CONCRETE
AND
CONSTRUCTIONAL ENGINEERING

INCLUDING PRESTRESSED CONCRETE

OCTOBER, 1954. **Vol. XLIX, No. 10**

FORTY-NINTH YEAR OF PUBLICATION

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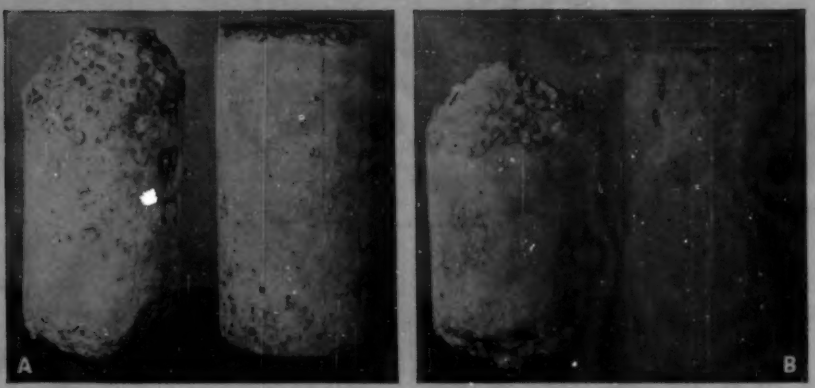

These illustrations are of 12in. x 6in. concrete cylinders, mixed 4-2-1 with water/cement ratio of 0.6 made to Code of Practice. For the left-hand cylinder in each case ordinary Portland Cement was used and for the right-hand cylinder, Sulphate-Resisting Cement. The cylinders in A were immersed in magnesium sulphate solution where the equivalent SO_3 content is 500 parts per 100,000. The cylinders shown in B were immersed in a sodium sulphate solution of similar SO_3 content. **The photographs were taken after the cylinders had been immersed for five years.** The value of using Sulphate-Resisting Cement for concrete work which is liable to the destructive action of soluble sulphates is clearly indicated since on the majority of sites the sulphate concentration seldom exceeds the equivalent SO_3 content of the solution used for the test.

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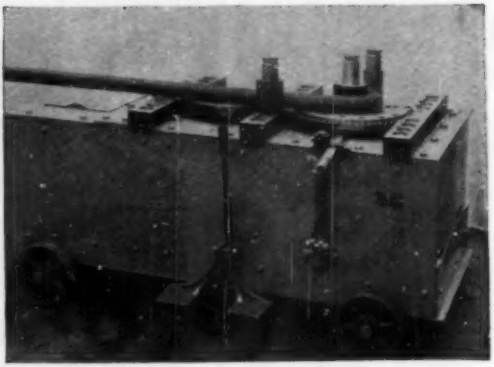

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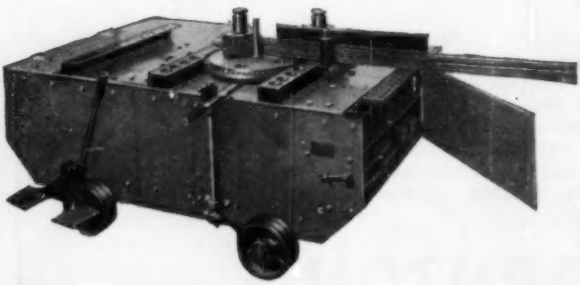

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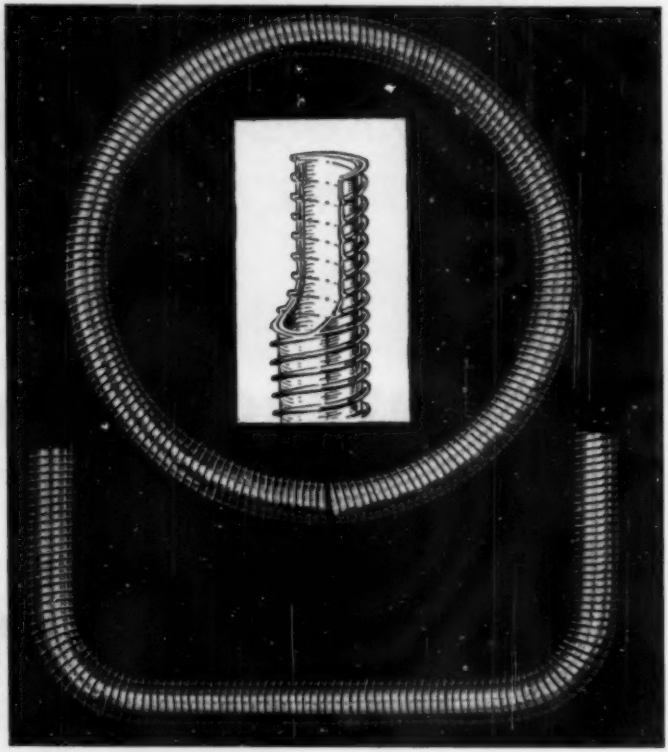

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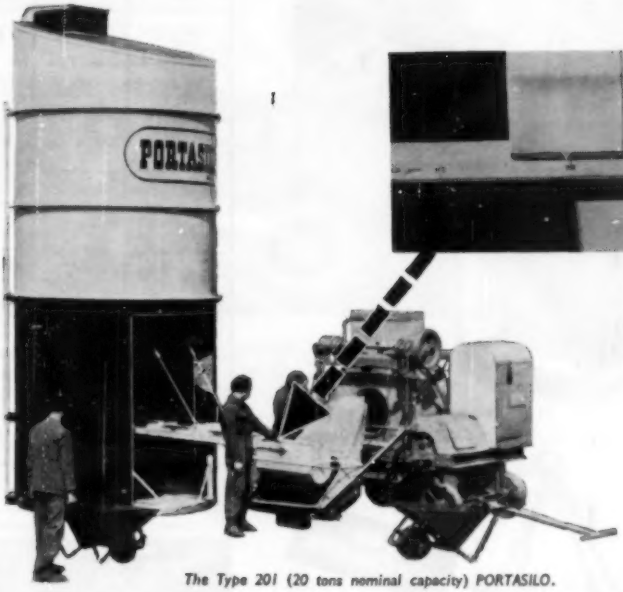

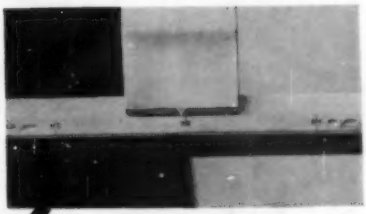

The automatic weighing device is instantly adjusted against the calibrated scale.

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Length 'B'	3' 10"	3' 3"	3' 3"
Width 'C'	3' 10"	3' 3"	2' 5"
Weight 'D'	3¼ cwt.	3 cwt.	2 cwt.
Overall Height inc. Chains 'E'	7' 6"	7' 4"	7' 2"
Construction 'H'	⅛" M.S. Plate 2" x 3/16" A/Iron		
Stand 'J1' x 'J2'	2" A/Iron 3' 0" x 2' 8"	2" A/Iron 2' 8" x 2' 4"	2" A/Iron 3' 0" x 2' 2"
'F1' x 'F2'	Discharge Gate		
Bottom	1' 10" x 10"	1' 6" x 11"	1' 5" x 11"
Side	1' 10" x 11"	1' 6" x 8"	1' 6" x 8"
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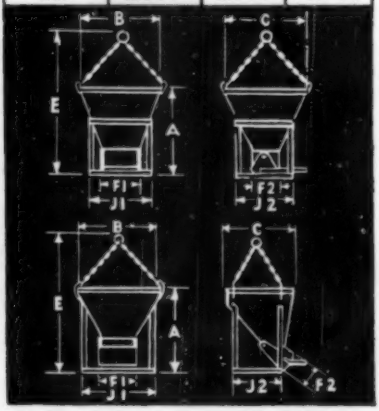

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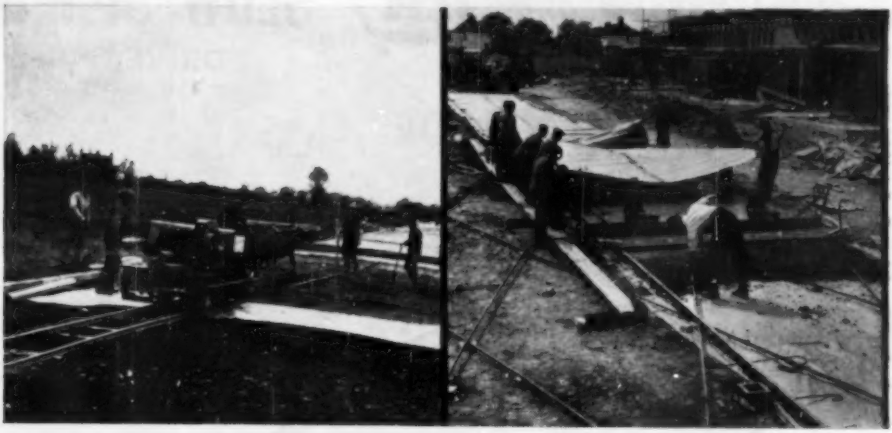

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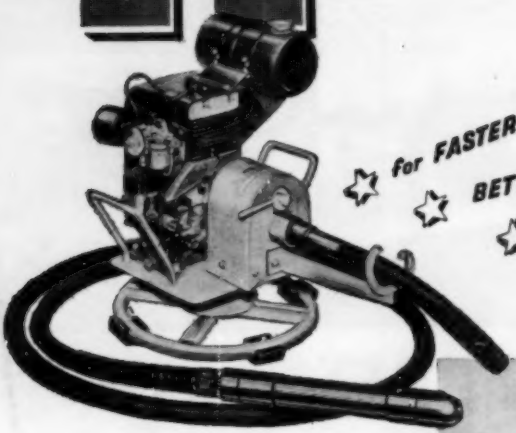
The Higher Frequency Vibrator with the

SLOW SPEED DRIVE



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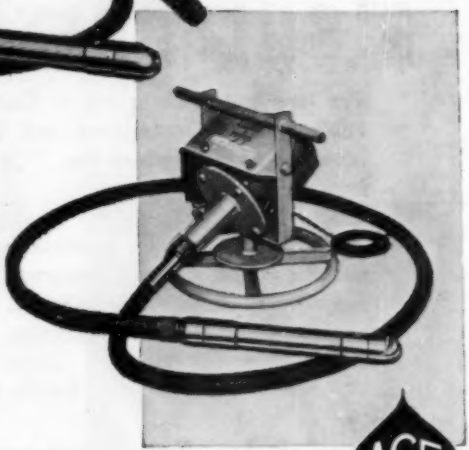
☆ LOWER COSTS



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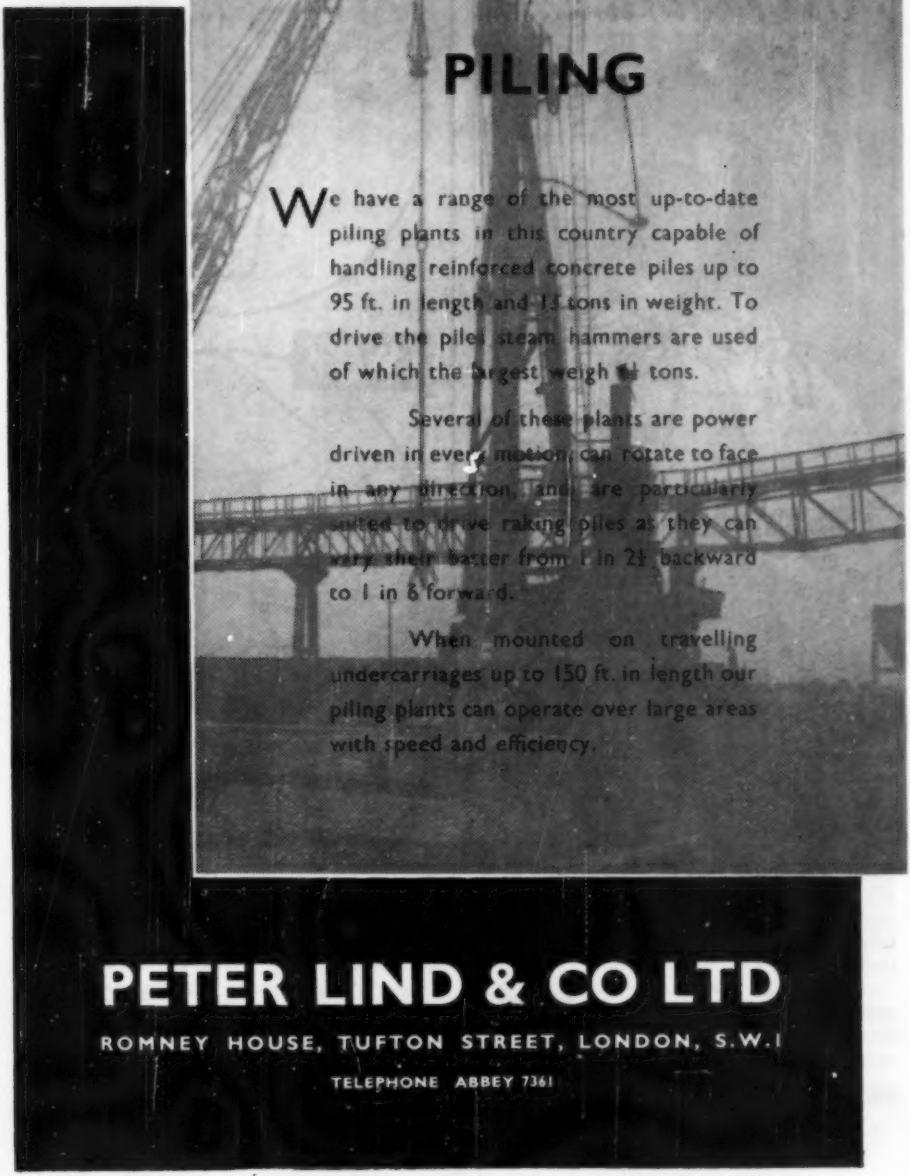
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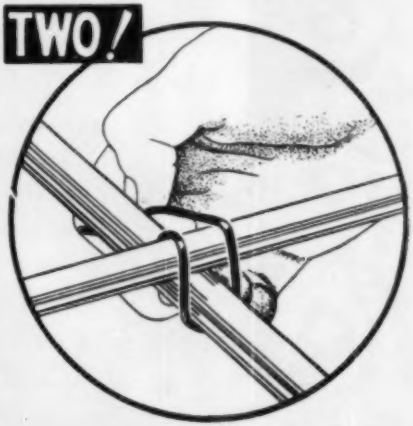

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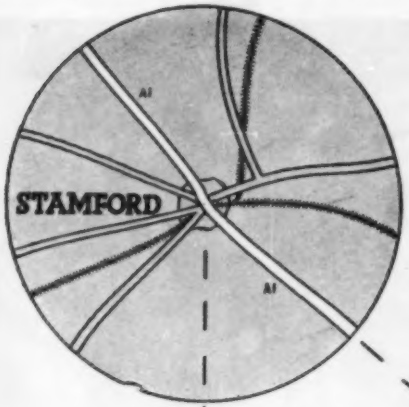

ANOTHER ANGLIAN PRESTRESSED PRODUCT

Prestressed concrete beams in use on the partly-completed road-over-rail bridge on the Great North Road at Stamford. This illustration shows one of several trunk road bridges at present under construction using "ANGLIAN" prestressed beams.

Photograph by courtesy of British Railways, Eastern Region. Contractors: Messrs. Wellerman Bros. Ltd., Sheffield

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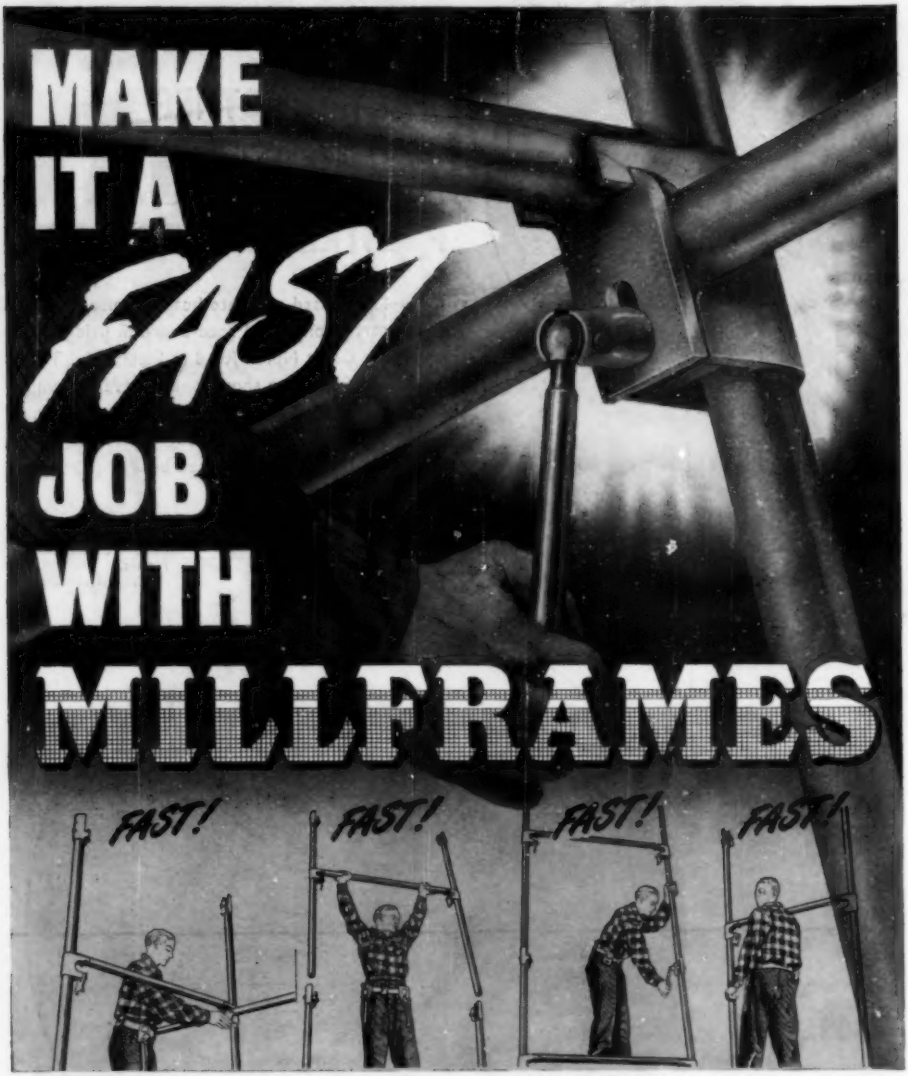

Horizontal tube inserted in Millframe Coupler. Half-turn the spring steel plate, tighten bolt—it's fast!

Going up. The next Millframe slides quickly into position on verticals of the H-FRAME below.

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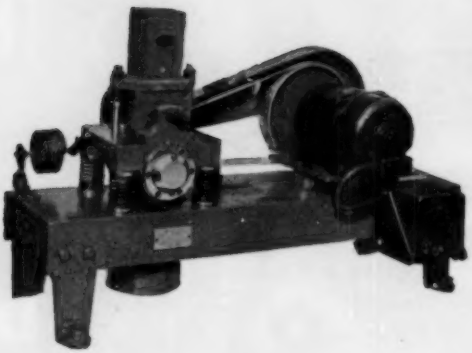

for compacting mortar cubes for Compression Test B.S. 12/1947, B.S. 915/1947, B.S. 146/1947, B.S. 1370/1947. New type automatic control—optional. The vibrator illustrated in the B.S. was built in our works.

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THE BASIC COMPONENTS

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Unistrut Bolt ¼" and ⅜" sizes.
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Unistrut Channel 10'-0" and 20'-0" standard lengths. 12 gauge.
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Assemble Fitting, Nut and Bolt—a turn of the spanner, it's done.

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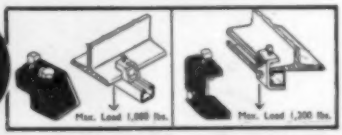
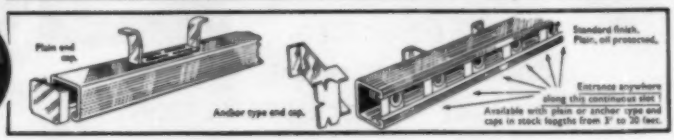
BEAM CLAMPS



ROLLER PIPE SUPPORTS

CABLE PIPE AND CONDUIT CLAMPS

CONCRETE INSERTS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Available with plain or anchor type end caps in stock lengths from 3" to 20 feet.

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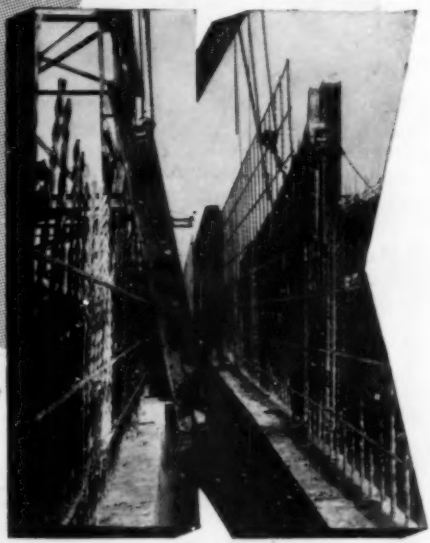
REINFORCED CONCRETE CONSTRUCTION



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Resident Engineer:
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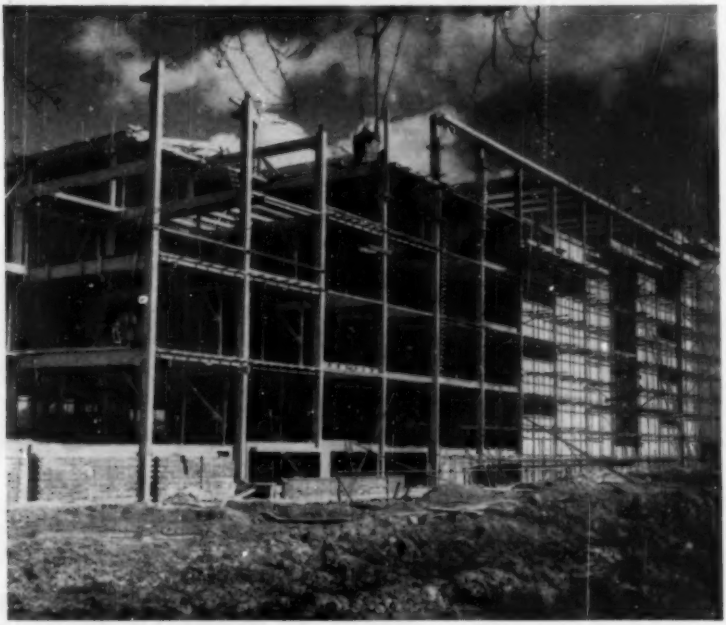

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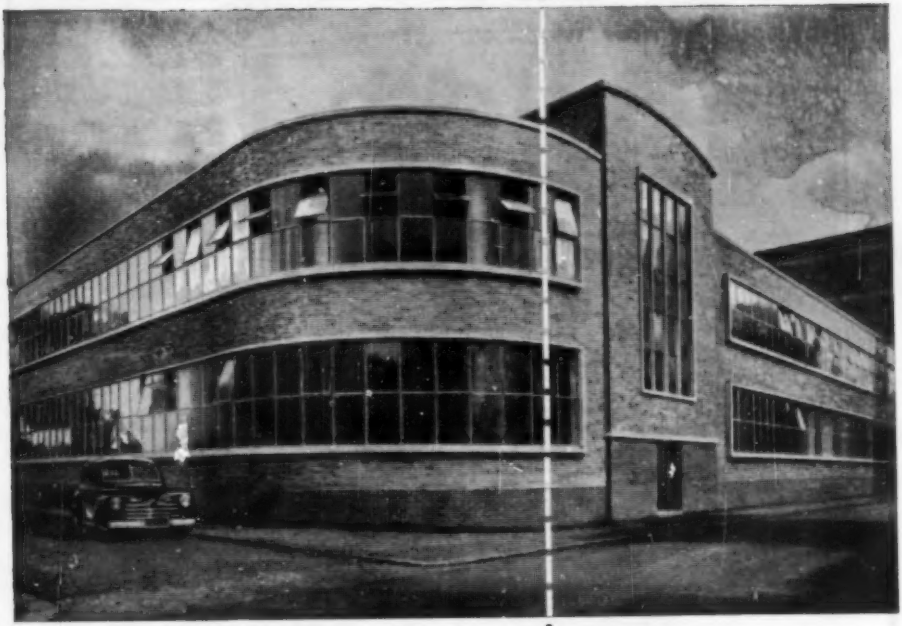

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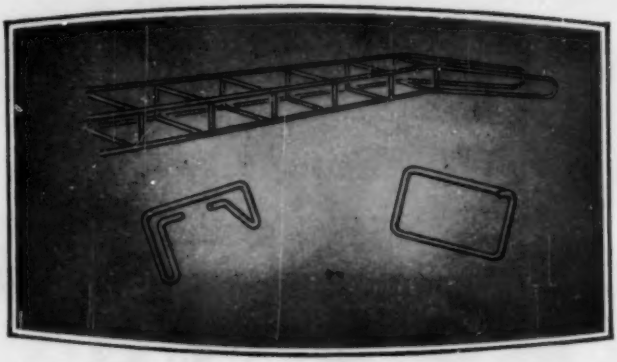

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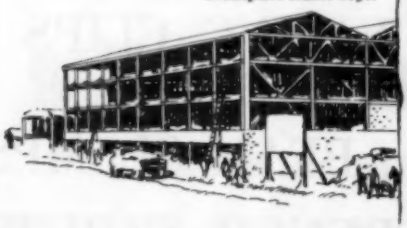

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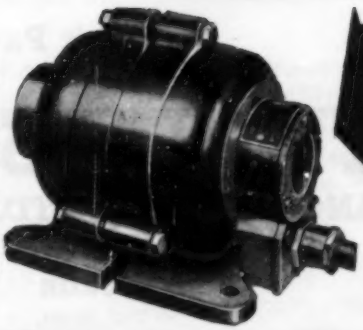

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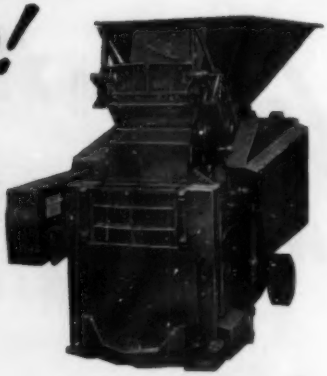

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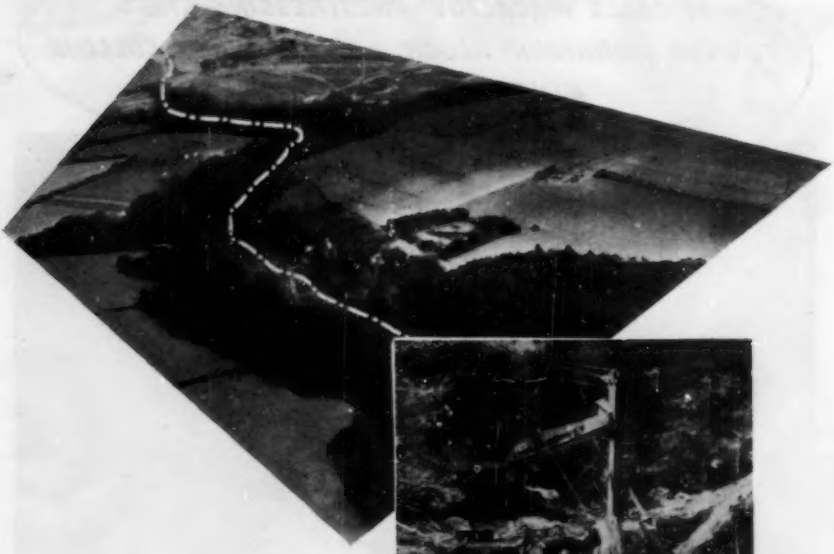

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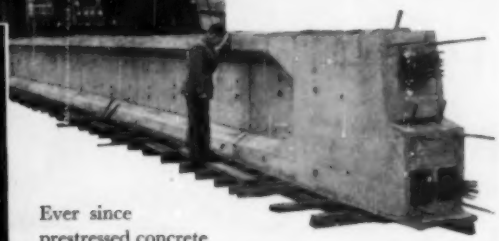

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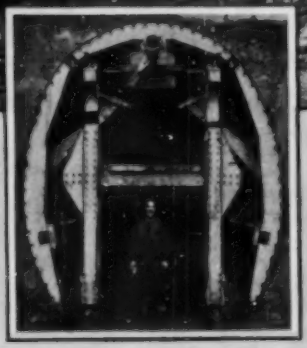

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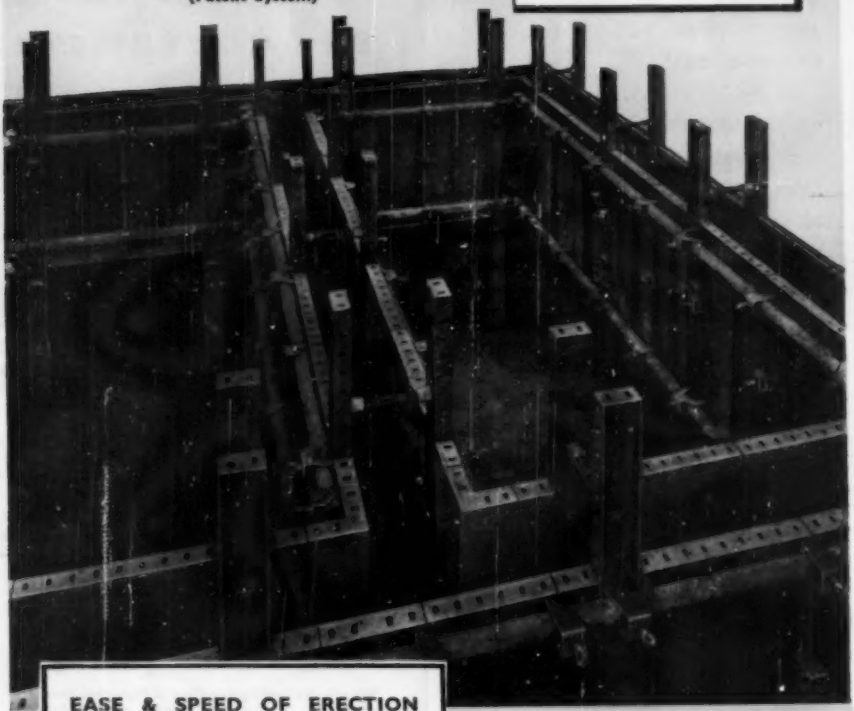

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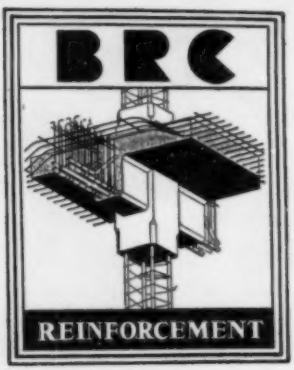

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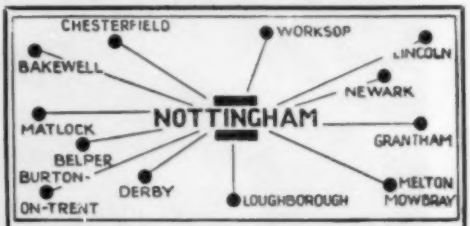

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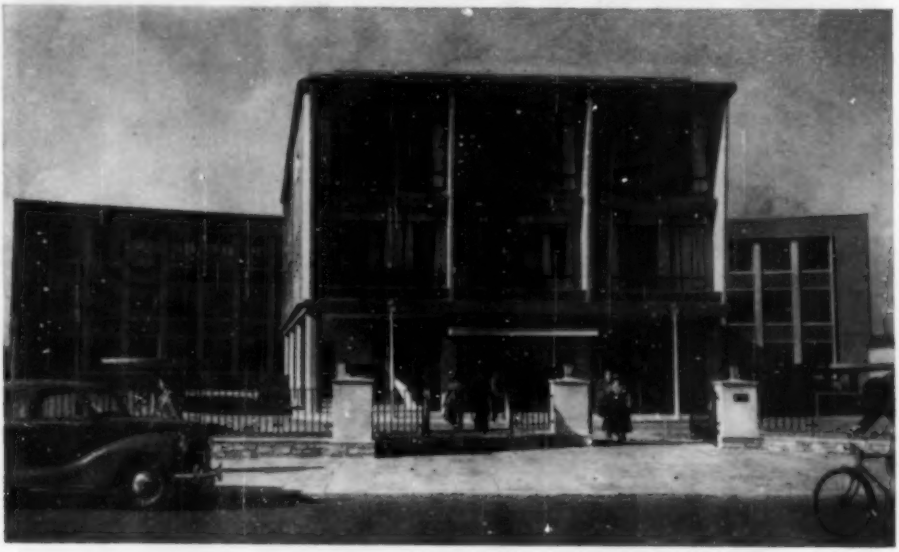

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Volume XLIX, No. 10. LONDON, OCTOBER, 1954.

EDITORIAL NOTES

The Engineer in Society.

IN recent years much has been said and written about " improving the status " of engineers. This is understandable when so many people are affiliated to an association whose purpose is to see that the standard of living of its members is better, or at least no worse, than that of others engaged in similar work. In the case of scientists and engineers, however, the propaganda for " improved status " is being increasingly bedevilled by claims that by reason of their training scientists and engineers are of all people most fitted to govern nations and the world. This is absurd. Ability to plan buildings and engineering works, to calculate forces and stresses, and some knowledge of mathematics are not the attributes we would look for in leaders of men or advisers on everyday affairs. We see no connection whatever between statesmanship and engineering. Some of the forces of nature are precisely predictable. Recommended values for most variable natural phenomena are laid down in regulations and codes. It is true that engineers should have imagination, but so must people in other walks of life if they are to be successful. A leader of men has to deal with the minds of men, and the responsiveness of men's minds cannot be found by the use of a slide rule or by geometry. It appears to be unfortunately true that the minds of many men can be guided in the same direction by skilful propaganda combined with penalties. This was shown in the 1930 s, when the conception of the master race was fostered by propaganda in conjunction with the labour camp and the loss of civil rights for unbelievers. The result was disastrous. The effect of the constant repetition of an idea is not a recent discovery. In his " Argument ", written nearly 2500 years ago, Aristotle said: " High-flown panegyrics on liberty, rights of man, social order, justice, the constitution, law, religion, and so on, will gradually lead the hearers to take for granted, without proof, that the measure proposed will lead to these evils or advantages, and it will in consequence become the object of groundless abhorrence or admiration. For the very utterance of such words as have a multitude of what may be called stimulating ideas associated with them will act like a charm on the minds, especially of the ignorant and unthinking, and raise such a tumult of feeling as will effectively blind their judgment, so that the string of vague abuse or panegyric will often have the effect of a train of sound argument."

It seems that some scientists and engineers are having their judgment

blinded by the constant repetition of unwarrantable statements to the effect that their training produces statesmen. For example, in a recent number of the Journal of the Engineers' Guild we read that " the engineer . . . is a representative of European culture ", " the engineer is predestined and prepared to render particularly valuable co-operation in resolving international political questions ", " there is every reason to have confidence in our own worth, for are not we [engineers] the most important profession on earth ? " These quotations contrast strangely with the view expressed in the same number that " the cream of the youth of to-day were not attracted to the engineering profession " ; or with the exhortations, also in the same number, that engineers should start to study and appreciate human values ; or with ridiculous statements such as that engineering was the earliest of the arts emerging with the first dawn of civilisation when the first tool was made by man—the first tool was probably a club used as a hammer, but its fashioning can hardly be called engineering. The claims that the affairs of men should be controlled by scientists and engineers cannot be reconciled with the concern so often expressed by educationists in and out of Parliament about the narrowness of mind of so many graduates in technical subjects. The statement that horse-power per head of population is the true index of civilisation has been repeated so often that " wishful thinkers " are in danger of believing such complete nonsense. Civilisation is a state of mind and of culture, and has nothing to do with machines—or luxury. Civilisation is the converse of barbarism, and recent history has shown how barbaric a highly-industrialised nation can be.

A mathematical system of reasoning applied to the solution of human problems could only treat human beings as ciphers or robots. The greatest contributors to civilisation have seldom been scientists, mathematicians, engineers, or specialists in any branch of learning, and some of the most civilised men in history knew horse-power only in the form of a quadruped. The wide claims made by some scientists and engineers that they are the proper people to control the affairs of men are not likely to be received with enthusiasm just now. Scientists invented the internal combustion engine which causes as many deaths and disablements every year as are incurred in a major war. They made possible bombing from the air, poison gas, bacterial warfare, the atom and hydrogen bombs, and other curses and fearful threats of our times. Indeed the peoples of the world could be excused if they were antagonistic to the whole body of scientists when so many of them are busy devising means of destroying humanity. It is said that the Chinese who first invented gunpowder was executed as an enemy of mankind—and to-day most people expect atomic energy to be the greatest danger the world has known instead of the great blessing that it might be.

There are undoubtedly leaders of men amongst engineers, but there is no reason to expect the proportion to be greater than in other walks of life. Engineers are as important to a community as people in other professions and trades, and more important than some, but this does not justify a claim that they are entitled to govern the rest of us. Another dictum of Aristotle is that when men with the same interests meet together they inevitably try to improve their own affairs. This is certainly true, and the furthering of the interests of its members is generally the sole or main purpose of an association—but it must be unique in history for the members of one profession (other than politicians) to claim that they are best fitted to control the affairs of the world.

The Design of Tee-beams.

By H. J. HOPKINS, D.F.C., M.A.(Oxon).

MOST published methods of designing tee-beams require the depth to be determined by trial and error with the aid of charts, or the use of complicated formulæ. There is a risk that these procedures may cause the designer to lose sight of the physical aspects of design. The simple method of obtaining the minimum depth described in the following emphasises the physical consequences of each step. It can be extended to the design of all tee-beams, for if the depth is greater than the minimum required it is necessary to determine only the lever arm and the area of steel.

The notation used is as follows: a, lever arm; A_s, area of steel; b, breadth of flange; b^1, breadth of rib; c, maximum permissible compressive stress in the

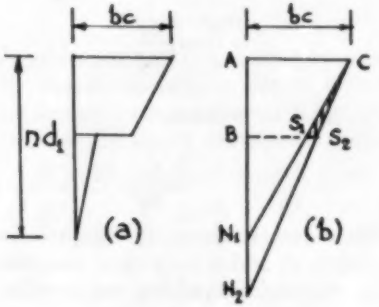

Fig. 1.

concrete; d, effective depth of beam; d_s, thickness of slab; m, modular ratio; n, proportion of effective depth in compression; t, maximum permissible tensile stress in the steel. The suffix 1 refers to the equivalent rectangular beam, and the suffix 2 to the corrected section.

Procedure.

The method consists of determining the effective depth d_1 required for the balanced design of an equivalent rectangular beam of breadth b, and multiplying d_1^2 by a single easily-determined factor to obtain d_2^2. It is based upon the following theory.

If the neutral plane lies in the slab, the required depth d_1 may be determined as for a rectangular beam. For this assumed condition nd_1 can be calculated. If this value is greater than d_s the distribution of the compressive force in the concrete is as *Fig.* 1(a) where the area of the trapezium gives the force in the flange and the area of the triangle gives the force in the rib. The compressive force in the rib is usually neglected, and it is neglected in this theoretical treatment. (Its inclusion does not, however, invalidate the method described, as the example shows.) The compressive-force diagram may therefore be considered as trapezoidal instead of triangular as for the equivalent rectangular beam. If no adjustment

of depth were made, then from *Fig.* 1(b) the maximum compressive stress in the tee-beam is $c \times \frac{ACN_1}{ACS_1B}$. If the effective depth is increased to d_2 then a smaller compressive force will resist the same bending moment.

Moreover, an increased depth will increase the area of the compressive-force diagram from ACS_1B to ACS_2B. Each of these effects will reduce the maximum compressive stress approximately in the proportion $\frac{d_1}{d_2}$, so that if d_2 is the required depth for maximum compressive stress c, then

$$\frac{d_2^2}{d_1^2} = \frac{ACN_1}{ACS_1B} = \frac{(nd_1)^2}{(nd_1)^2 - (nd_1 - d_s)^2}.$$

The required compressive force $= (ACN_1) \times \frac{a_1}{a_2}$

$$= \tfrac{1}{2}bnd_1c\frac{a_1}{a_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

As $\frac{d_1}{d_2} \simeq \frac{a_1}{a_2}$, equation (1) may be written,

$$\tfrac{1}{2}bnd_1c\frac{d_1}{d_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1a)$$

This approximation slightly overestimates the compressive force.

With an effective depth d_2 and a maximum compressive stress c the compressive-force diagram is trapezoidal and the compressive force is

$$\frac{(2nd_2 - d_s)}{2nd_2}bd_sc \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Equating (1*a*) and (2),

$$\left(\frac{2nd_2 - d_s}{2nd_2}\right)bd_sc = \tfrac{1}{2}bnd_1c\frac{d_1}{d_2} \quad . \quad . \quad . \quad . \quad (3)$$

$$\frac{d_2^2}{d_1^2} = \frac{nd_1nd_2}{d_s\left(2nd_1 - \frac{d_1}{d_2}d_s\right)} = \frac{(nd_1)^2}{d_s\frac{d_1}{d_2}\left(2nd_1 - \frac{d_1}{d_2}d_s\right)},$$

or

$$\frac{d_2^2}{d_1^2} = \frac{(nd_1)^2}{(nd_1)^2 - \left(nd_1 - \frac{d_1}{d_2}d_s\right)^2}.$$

As $\left(nd_1 - \frac{d_1}{d_2}d_s\right)^2$ is small compared with $(nd_1)^2$ the error introduced in writing $\frac{d_1}{d_2}d_s$ as d_s is small. Hence

$$\frac{d_2^2}{d_1^2} \simeq \frac{(nd_1)^2}{(nd_1)^2 - (nd_1 - d_s)^2}.$$

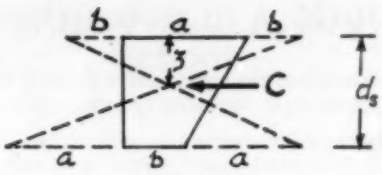

Fig. 2.

This approximation underestimates d_2^2 by an amount which nearly cancels the slight overestimation previously introduced.

Hence the required effective depth is given by

$$d_2^2 = d_1^2 \times \frac{(nd_1)^2}{(nd_1)^2 - (nd_1 - d_s)^2} \quad . \quad . \quad . \quad . \quad (4)$$

Lever Arm.

The lever arm of a tee-beam is best determined by considering the properties of a trapezium, using the figures obtained in design rather than a formula. In *Fig.* 2 the resultant compressive force acts through the centre of the area of the trapezium. Its distance from the upper compressed surface is

$$z = \frac{(a + 2b)}{3(a + b)} d_s = \frac{nd_2 + 2(nd_2 - d_s)}{3[nd_2 + (nd_2 - d_s)]} d_s.$$

The lever arm is $d_2 - z$.

Example.

Design a tee-beam with a flange 60 in. wide and a slab 5 in. thick for a bending moment of 4,000,000 in.-lb. (The working stresses are c, 1000 lb. per square inch ; t, 18,000 lb. per square inch ; m, 15.)

For these stresses $n = \frac{5}{11}$, and $R = \frac{c}{2} n \left(1 - \frac{n}{3}\right) = 192$.

Step (1). Determine $d_1 . d_1^2 = \frac{4{,}000{,}000}{60 \times 192} = 347$.

$$d_1 = 18{\cdot}6 \text{ in.} \quad nd_1 = \tfrac{5}{11} \times 18{\cdot}6 = 8{\cdot}45 \text{ in.}$$

Step (2). Determine $d_2 . d_2^2 = 347 \times \frac{8{\cdot}45^2}{8{\cdot}45^2 - 3{\cdot}45^2} = 416$.

$$d_2 = 20{\cdot}4 \text{ in.} \quad nd_2 = 9{\cdot}26 \text{ in.}$$

Step (3). Determine the lever arm.

$$a_2 = d_2 - \left[\frac{9{\cdot}26 + (2 \times 4{\cdot}26)}{3(9{\cdot}26 + 4{\cdot}26)}\right] \times 5 = 20{\cdot}4 - 2{\cdot}2 = 18{\cdot}2 \text{ in.}$$

Step (4). Determine the area of steel. $A_s = \frac{4{,}000{,}000}{18{,}000 \times 18{\cdot}2} = 12{\cdot}2$ sq. in.

Step (5). Check the stress in the concrete. (If the designer is satisfied with the theory upon which the method is based, this step may be eliminated.)

$$c\left(\frac{6{\cdot}76}{9{\cdot}26}\right) \times 5 \times 60 \times 18{\cdot}2 = 4{,}000{,}000. \quad c = 990 \text{ lb. per square inch.}$$

Alternative procedure when the compressive force in the rib, 1 ft. 8 in. wide, is taken into account.

Step (1).—As before.

Step (2).—

$$d_2^2 = \frac{8{\cdot}45^2}{8{\cdot}45^2 - \left(\frac{40}{60} \times 3{\cdot}45^2\right)} \times 347 = 390. \quad d_2 = 19{\cdot}75 \text{ in.} \quad nd_2 = 9 \text{ in.}$$

Step (3).—$a_2 = d_2 - \frac{17 \times 5}{39} = 19{\cdot}75 - 2{\cdot}18 = 17{\cdot}57$ in.

$$\text{Less } \frac{5\frac{1}{8}}{70\frac{1}{8}} \times (2{\cdot}82 + 1{\cdot}33) = \frac{0{\cdot}31}{17{\cdot}26} \text{ in.}$$

Step (4).—Area of steel $= \frac{4{,}000{,}000}{18{,}000 \times 17{\cdot}26} = 12{\cdot}9$ sq. in.

Step (5).—Stress in the concrete $= \frac{4{,}000{,}000}{\left[\left(\frac{6{\cdot}5}{9{\cdot}0} \times 5 \times 60\right) + \left(\frac{\ }{9} \times 4 \times 20\right)\right] \times 17{\cdot}26}$

$= 990$ lb. per square inch.

Book Reviews.

Bestimmungen des Deutschen Ausschusses fur Stahlbeton." (Berlin: Wilhelm Ernst & Sohn. 1954. Price 2.50 D.M.)

THIS is the second supplement to the fifth edition of the German code of practice for reinforced concrete. It deals with four subjects, namely, the deterioration of concrete due to the action of soil waters, the impact method of testing concrete, the use of internal vibrators, and the use of plate vibrators. Except for some mathematical expressions that are said to be useful in deciding the period of vibration, the contents of these supplements are statements of common knowledge.

"Bemessung im Stahlbetonbau." DIN 1040 (Entwurf). (Berlin: Wilhelm Ernst & Sohn. Price 4.30 D.M.)

THIS German code gives in draft form recommendations for the calculation of reinforced concrete members. Many of the suggestions made are already known in Great Britain. Pucher's method of calculating beams with and without compressive reinforcement where simple bending is treated as a particular case of bending combined with axial forces is, however, new, and some account of it was given in this journal for September, 1954. The design of slabs and beams is completely calculated by the use of a few simple equations and two tables; the derivations are independent of units and can be applied to any system of weights and measures.

"Der Stahlbetonbau." Vol. II. By Kersten and Kuhnert. 18th Ed. (Berlin: Wilhelm Ernst & Sohn. 1954. Price 19 D.M.)

THIS is a complete revision of the 1949 edition. New chapters have been added, and all are enlarged and brought up to date. This volume deals with floors, columns, staircases, cantilevers, multiple-story buildings (including prestressing), roofs, precast buildings, foundations, walls, hydraulic structures, pipes and ducts, water-retaining structures, silos, cooling towers. Many useful details are shown. This is a practical book, of great use to engineers specialising in reinforced concrete.

Precast Construction in a Multiple-story School.

STANDARDISATION OF MEMBERS.

A SECONDARY technical school to accommodate 600 children at Worthing, covering an area of between 53,000 and 54,000 sq. ft., is being used as a prototype for the "Intergrid" system of construction. This system was designed for buildings of up to four stories, and comprises light prestressed frames and precast panels to form the floors and outer leaves of the walls, all of which conform to a module of 3 ft. 4 in. The heights of the stories are governed by the lengths of the columns.

primary floor beams is 23 ft. 4 in. and of roof beams 36 ft. 4 in. If secondary beams are used with the primary beams, bays 33 ft. 4 in. square for floors and 40 ft. square for roofs may be constructed.

No fixed scaffolding is used in the construction of the walls, floors, or roofs, but the columns are erected in small portable scaffold frames. When the columns and beams are in place, all the other components are fixed from inside the building.

COLUMNS.—There are four standard

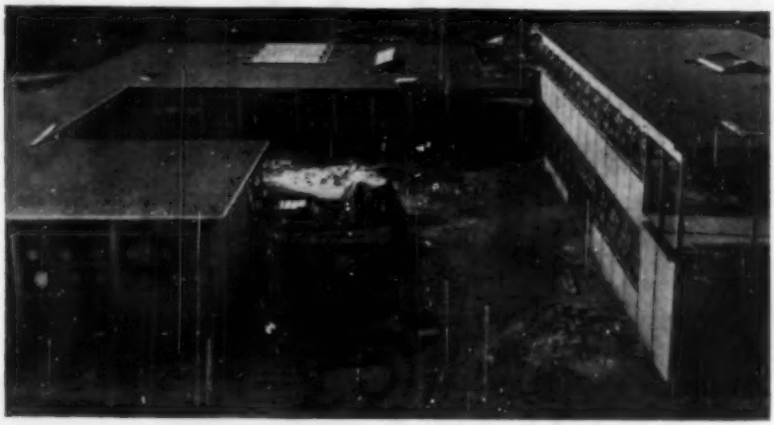

Fig. 1.—Two Partly-completed Buildings.

The general arrangement of the structure is shown in *Fig.* 2, and *Fig.* 1 shows two partly-completed buildings. The floor and roof slabs are supported on post-tensioned lattice beams at 3 ft. 4 in. centres, normally in both directions, and these are in turn supported on boundary beams or the columns. If the span or loading does not require the use of a standard secondary beam, a shallow beam of similar size to the top boom of a standard beam is used. The columns are at either 6 ft. 8 in. or 10 ft. centres along the sides of each bay. The sizes of the bays are determined by the lengths of the beams. Normally the maximum span of

columns (*Fig.* 3), all of which have overall cross-sectional dimensions of 6½ in. by 4½ in. Column C1 is used in intermediate positions in external walls, columns C2 and C3 at corners and re-entrant angles respectively of the outer walls, and C6 is used in any internal position. Three types of columns (C1, C2, and C3) have holes at 10-in. centres and grooves or rebates in their sides so that the external wall slabs may be fixed to them. Each column is prestressed with four 0·2-in. diameter wires. There is also a column of cruciform section 6½ in. by 6½ in. overall in cross section. The columns vary in height between 8 ft. 4 in. and

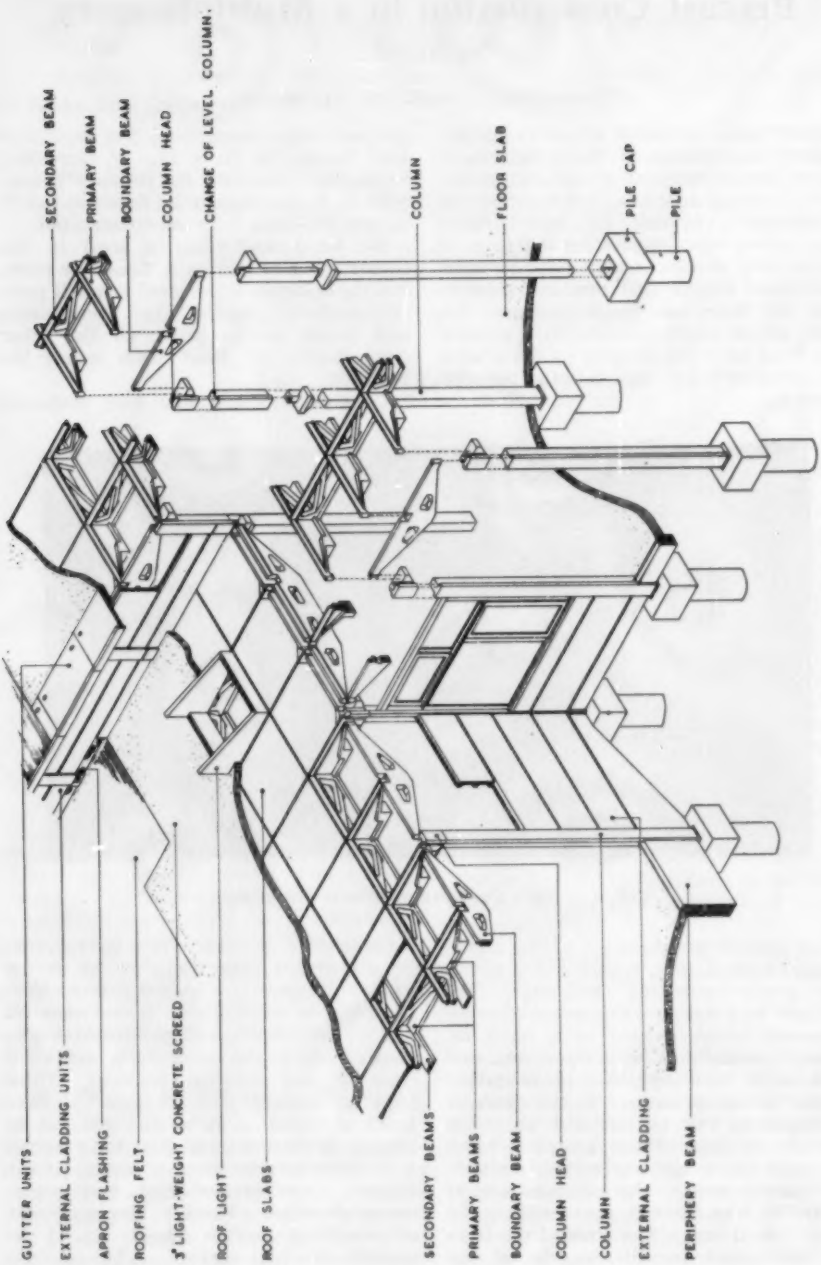

Fig. 2.—Method of Construction.

18 ft. 4 in. by increments of 10 in. The ground-floor columns are generally erected in pockets formed in the bases, but as this school is founded on bored piles the pockets are formed in the tops of the pile caps (*Fig.* 2). On the upper floors the columns are placed on the columns of the floor below. The upper column is joined to the column-head with a bolt which acts as a dowel.

COLUMN HEADS.—There are four main types of column heads (*Fig.* 3) for use with the four standard columns; these column heads are lightly reinforced and are provided with dowel holes which allow beams to be joined to the columns from both directions (*Fig.* 4). In addition there are other types of column heads which, at changes in floor or roof levels (*Fig.* 5), allow beams on opposite sides of a column to be joined to them.

BEAMS.—Three types of beam are used, namely reinforced concrete boundary beams, and prestressed primary and secondary beams which are both made up of a number of units.

The boundary beams (*Fig.* 6) are 3 in. wide and 1 ft. 4 in. deep, reinforced with steel bars, in two standard lengths to span between columns at 6 ft. 8 in. or 10 ft. centres. The tops are recessed to form connections for the primary and secondary beams which they support; a beam 6 ft. 8 in. long supports one primary or secondary beam, and a beam 10 ft. long supports two primary or secondary beams.

Fig. 4.—Beams Joined to a Column.

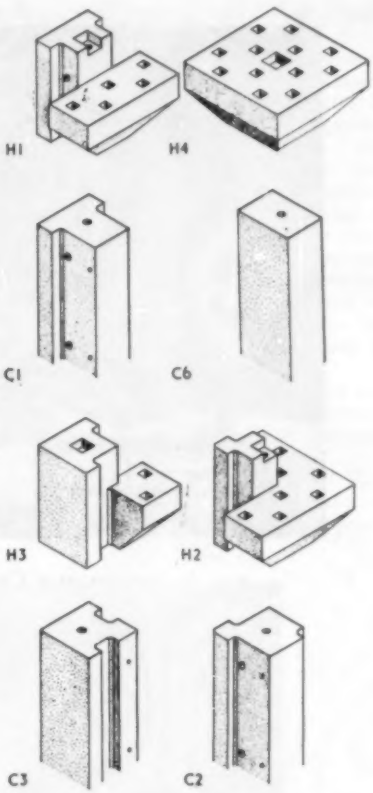

Fig. 3.—Types of Columns and Column Heads.

The centre-line of the boundary beams is 2½ in. inside the grid-line; this enables a double row of beams to be used where two bays meet and allows the outer walls to continue uninterruptedly past the boundary beams at each story height. Where boundary beams are in pairs they are supported on the same column-head. In the sides of the boundary beams are holes corresponding to the spaces between the members of the internal beams to allow services to be placed within the depth of the floor.

The primary beams are at 3 ft. 4 in. centres across the shorter span of each bay (*Fig.* 7). They consist of two solid precast units 3 ft. 4 in. long which form the ends of the beam and a varying number of identical precast intermediate units

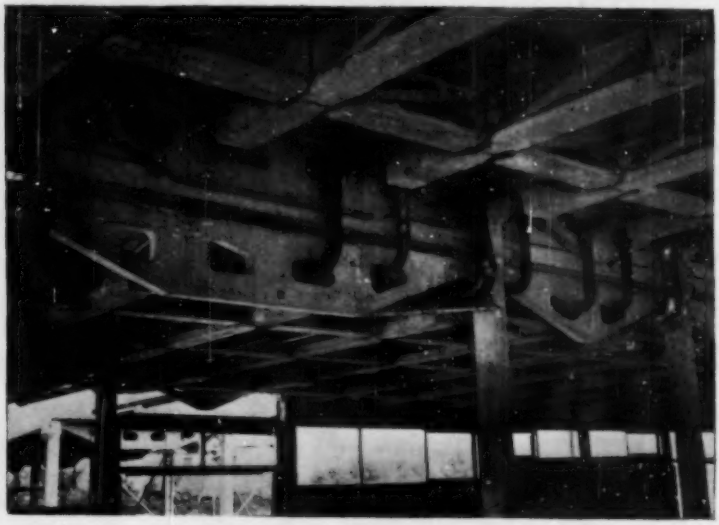

Fig. 5.—Beams at a Change in Floor or Roof Level.

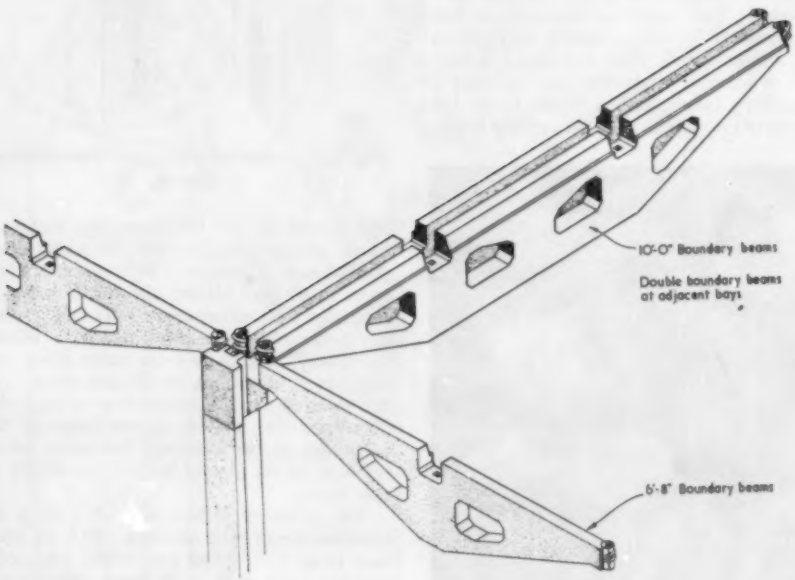

Fig. 6.—Boundary Beams.

each 3 ft. 4 in. long and 12¾ in. deep (*Fig.* 8). These units are assembled at the site before erection to form beams that are multiples of 3 ft. 4 in. in length. The top and bottom booms of each unit are jointed with high-alumina cement mortar which is allowed twenty-four hours to harden. The assembled units are then prestressed together by either four or eight 0·2-in. diameter wires according to their length and the load they are designed to carry. One wire, or one pair of wires, is anchored at one end of the beam and passes in a groove to the opposite end, where it is looped and returned to the first end where it is tensioned and anchored. This process is repeated for the second wire, or pair of wires, in the reverse direction. Two types of end unit are used : in one, a single wire is formed into a loop and the ends are fixed by one anchor ; in the other, two wires are formed into loops and each pair of wires is anchored separately. The exposed wires in the grooves are covered with grout.

The secondary beams (*Fig.* 9) comprise units similar to those of the primary beams except that the web projects at each end so that they may be supported on the flanges of primary beams. The joints are then mortared and the prestressing wires are passed along the groove in the outer edge of the lower flange of the units and through a hole left for them in the primary beam. The prestressing force is applied when all the secondary beams in a bay have been placed and the mortar in the joints has hardened. The grooves with the prestressing wires in them are grouted.

The gymnasium is 50 ft. long ; its roof beams are slightly different from those of other roofs, the units being prestressed together by one 12-wire cable.

Floor and Roof Slabs.—The floor and roof slabs, which are of unreinforced concrete, are nominally 3 ft. 4 in. square,

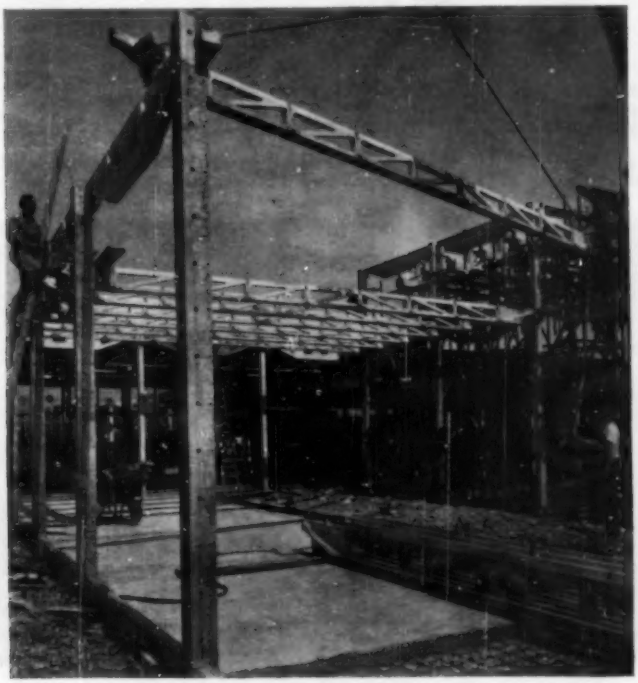

Fig. 7.—A Primary Beam being lifted into Position.

2¾ in. thick at the edges, and 1¼ in. thick at the middle, their undersides being slightly domed. They are placed within the squares formed by the top flanges of the beams upon which they are supported (*Fig.* 11). When the slabs are grouted and covered with a cement-mortar topping 1¼ in. thick the floor becomes a rigid slab ; the roof is covered with foamed-slag concrete 3 in. thick and two layers of roofing felt, and is finished with granite chippings. Where top lighting is required roof lights are used instead of normal roof slabs. The kerbs for the roof-lights are nominally 3 ft. 4 in. square, and can be used singly or may be erected side by side to support roof-lights of any length that is a multiple of 3 ft. 4 in.

Eaves units project 12 in. beyond the face of the external wall to form a fascia 4½ in. deep. There are standard units nominally 3 ft. 4 in. long for re-entrant angles and corners and for use where the roof-level changes. They are bedded in mortar and are fixed with bolted galvanized steel stirrups which pass under the end units of the beams.

STAIRCASES.—The staircase wells were cast in situ and the stringer-beams were precast and prestressed in a factory. A cable of eight wires was used, the profile of the cable conforming to the two cranks

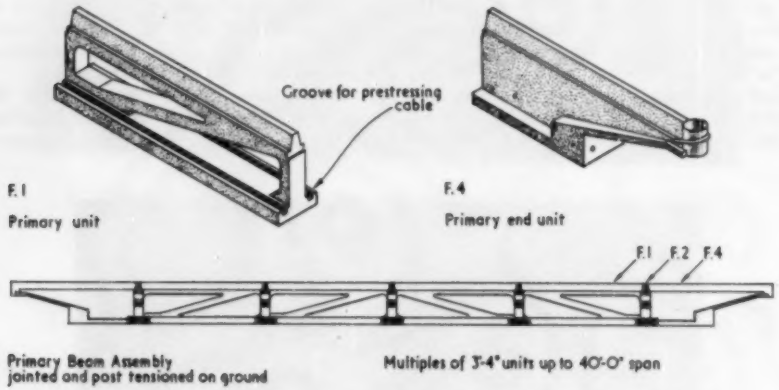

Fig. 8.—Details of Primary Beams.

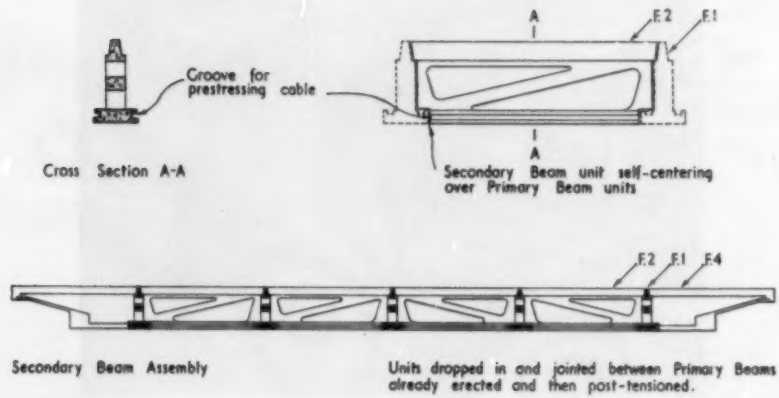

Fig. 9.—Details of Secondary Beams.

in the member. Reinforcement bars were also used to enable the stringers to be handled. Standard reinforced concrete stair treads, which allow adjustment for different floor-to-floor heights, were used and similar treads are also used to form the landings.

WALLS.—The external walls consist of an internal leaf of precast plaster slabs 3 in. thick, an external leaf of precast concrete slabs, and a cavity of 1 in.

The concrete slabs are 1½ in. thick with horizontal and vertical ribs 3 in. thick (*Fig.* 10). They span between columns at 6 ft. 8 in. or 10 ft. centres and are generally 1 ft. 8 in. high. Slabs 10 in. high are used if they are required at window openings. No special lengths of slabs are used at re-entrant angles or corners. A slab 5 in. high is used at upstands at ground-floor level. Three different types of exposed aggregate finish are used and the special face mixtures were vibrated into the surfaces of the slabs. The finishes are Derbyshire spar and white cement to produce a white surface, calcined flint mixed with a proportion of shingle to produce a light brown colour, and black granite and high-alumina cement.

The slabs fit into the grooves of the columns and are fixed by means of reinforced concrete pins (*Fig.* 10). Holes in the end ribs of the slabs correspond to holes in the column; the holes are lined with grout and a tapered precast concrete

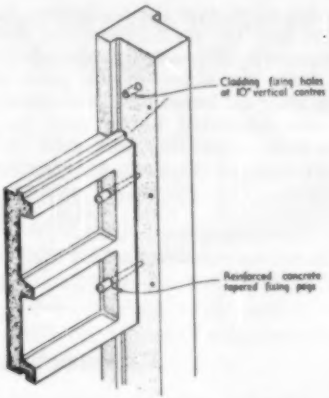

Fig. 10.—Method of Fixing Wall Slabs.

pin is driven into them to form a rigid fixing. Some sections of wall slabs were subjected to powerful jets of water for six hours and they proved to be waterproof.

GENERAL.—The floors were designed to carry a total superimposed load of 90 lb. per square foot including 15 lb. per square foot for floor finishes and 15 lb. per square foot for partitions. The roofs were designed for a total superimposed load of 37½ lb. per square foot including the weights of woodwool insulation, topping, and live load. The specification required that the average crushing strength of the

Fig. 11.—A Partly-completed Roof.

concrete at 28 days should be 8200 lb. per square inch for the columns and 7600 lb. per square inch for other precast members. The force remaining in the prestressing wires after all losses had been accounted for was estimated to be 4000 lb. An ultra-sonic apparatus was used to test 60 per cent. of the units for compressive strength. The Freyssinet system was employed, and 2-wire, 8-wire, and 12-wire anchorages were used.

The school was designed for the Worthing Borough Council by the Architects and Building Branch of the Ministry of Education in association with the County Architect's Department of West Sussex. The system was designed by the Pre-Stressed Concrete Co., Ltd., and Messrs. Gilbert-Ash, Ltd., the main contractors, who are the joint proprietors of the system. The prestressed columns and stringers were made by the Liverpool Artificial Stone Co., Ltd., and the other precast members by Mono Concrete, Ltd.

Research on Concrete Roads.

THE following notes are abstracted from the Report of the Road Research Board for the year 1953 (published by H.M. Stationery Office. Price 5*s*.)

An Experimental Road.

The experimental concrete road at Oxton, Nottinghamshire, has been open to traffic for five years. The road carries about 800 vehicles per day, of which half are cars and light vans, about 15 per cent. heavy vans and light lorries, and about 35 per cent. heavy lorries. The plain concrete slabs 7 in. and 8 in. thick are in a satisfactory condition, but the thinner plain slabs are either badly cracked or have failed completely. Reinforced concrete slabs from 3 in. to 8 in. thick provide a satisfactory running surface, although those 6 in. thick and less contain many hair cracks which are, however, held together by the reinforcement. Cracking and spalling have occurred at the joints in the reinforced slabs 3 in. and 4 in. thick. Cracking is greatest in the bays adjacent to expansion joints, and most of the transverse cracks started at the longitudinal joint. Plain and reinforced slabs of thicknesses up to 6 in. on a cement-stabilized sand base behaved no better than those laid directly upon the sub-grade, which was a well-graded gravelly sand.

Stresses in Roads.

In experiments at Sapcote Junction it was found that, whereas the stress in the road surface produced by a vehicle travelling at 30 miles per hour rose to a maximum and fell again in one-fiftieth of a second, the stress in the subgrade 2 in. below the base (total thickness of road structure 17½ in.) persisted for about a quarter of a second. When the load on the axle of a moving lorry was trebled, it was spread by the tyre so that the stress in the road surface increased only slightly, but the stress in the subgrade just beneath the base was almost trebled. This is in accordance with the mathematical theory of the loading of a two-layer system given in Road Research Technical Paper No. 9. The stresses in the subgrade in general were found to be some 30 per cent. greater in spring than in autumn.

Effect of Bituminous Surfaces on Temperatures in a Slab.

The presence of a bituminous surface affects the temperature of the concrete slab beneath it. The black surface increases the amount of radiant heat absorbed, but the thermal insulation provided by the surface counterbalances this effect. The stresses in the slab due to temperature changes and the movements at the joints due to changes in the mean temperature of a slab are therefore both affected by the bituminous surface. Experiments have shown that the effect of the surface on the mean temperature of a slab 8 in. thick was to increase it by up to 25 per cent. with a ¼-in. surface, by about 18 per cent. with a 1-in. surface, and by about 5 per cent. with a 2-in. surface. The increases in temperature gradient were 25 per cent. with a ¼-in. surface, 8 per cent. with a 1-in. surface, and nil with a 2-in. surface.

Analysis of Statically-indeterminate Structures by the Deformation Method.—IV.*

By M. SMOLIRA, Ph.D., A.M.Inst.C.E., D.I.C.

Continuous Frames with Curved Members.

CONTINUOUS frames with curved members can be analysed in a similar way to single-span frames discussed in Part II, except that generally, in addition to angular gaps, linear gaps must be closed simultaneously by statically-indeterminate bending moments and forces. Only in the case of two-span frames may the equations for linear gaps be avoided if it is assumed that joint B is at its final position at B′ (*Fig.* 37), while joints A and C have moved to A′ and C′ in a statically-determinate condition and will move finally to A″ and C″ when statically-indeterminate bending moments and forces are applied.

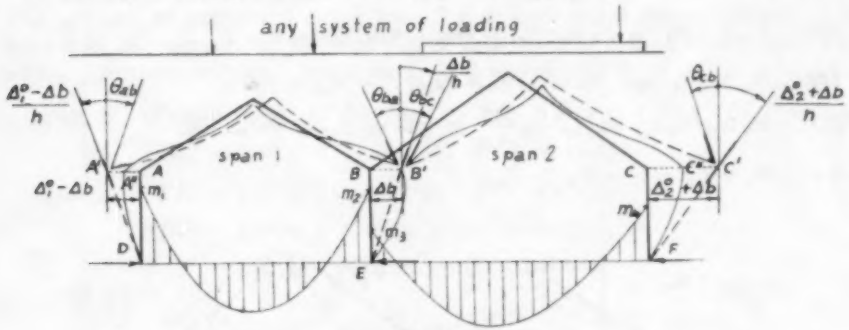

Fig. 37.

Two-span Frames with Curved Members.—Following this procedure for frames with two spans, only translation Δb of joint B will enter into equations of equilibrium, and no equations for linear gaps will be required. The translations Δa and Δc of joints A and C, if required, can be calculated separately.

In a general case of two-span frames, of any shape and with any system of loading, the angular gaps at A, B, and C, in the condition relaxed from the effect of continuity of joints, are as shown in *Fig.* 37, in which Δ_1^o and Δ_2^o are horizontal translations of joints in the first and second span in a statically-determinate case. Other symbols are as defined previously. The equations of equilibrium for the joints A, B and C can now be set out as follows:

$$
\left.
\begin{aligned}
&\text{DAB.} \quad m_1.\alpha_{ab} + m_1.\alpha_{ad} + m_2.\beta_1 + m_1.\frac{\Delta_1^{ma}}{h} + m_2\frac{\Delta_1^{mc}}{h} + H_d.\gamma_1 + H_d.\frac{\Delta_1^h}{h} = \theta_{ab} + \frac{\Delta_1^o - \Delta b}{h} \\
&\text{ABC...} \quad m_1.\beta_1 + m_2.\alpha_{ba} + m_3\alpha_{bc} + m_4.\beta_2 + H_d.\delta_1 + H_f.\gamma_2 = \theta_{ba} + \theta_{bc} \\
&\text{ABE...} \quad m_1.\beta_1 + m_2.\alpha_{ba} + (m_2 - m_3).\alpha_{be} + H_d.\delta_1 = \theta_{ba} + \frac{\Delta b}{h} \\
&\text{BCF..} \quad m_3.\beta_2 + m_4.\alpha_{cb} + m_4.\alpha_{cf} + m_3.\frac{\Delta_2^{mb}}{h} + m_4\frac{\Delta_2^{mc}}{h} + H_f.\delta_2 + H_f.\frac{\Delta_2^h}{h} = \theta_{cb} + \frac{\Delta_2^o + \Delta b}{h} \\
&\text{S.c.} \quad m_1 = (m_2 - m_3) + m_4
\end{aligned}
\right\} \quad (64)
$$

* Previous articles appeared in this journal for July, August and September, 1954.

For symmetrical frames and symmetrical systems of loading, only the first two equations are required, in which case $\Delta b = 0$.

When bending moments are calculated from (64), the translations of joints A and C can be obtained from

$$\Delta a = \Delta_1^{\circ} - \Delta b - m_1 . \Delta_1^{ma} - m_2 . \Delta_1^{mb} - H_d . \Delta_1^{h}$$

$$\Delta c = \Delta_2^{\circ} + \Delta b - m_4 . \Delta_2^{mc} - m_3 . \Delta_2^{mb} - H_f . \Delta_2^{h}$$

If one span only is loaded (*Fig.* 38), equations (64) require slight alteration as follows:

$$\left.\begin{aligned}
&\text{DAB} \ldots m_1 . \alpha_{ab} + m_1 . \alpha_{ad} + m_1 . \frac{\Delta_1^{ma}}{h} + m_2 . \beta_1 + m_2 . \frac{\Delta_1^{mb}}{h} + H_d . \gamma_1 + H_d . \frac{\Delta_1^{h}}{h} = \theta_{ab} + \frac{\Delta_1^{\circ} - \Delta b}{h} \\
&\text{ABC} \ldots m_1 . \beta_1 + m_2 . \alpha_{ba} - m_3 . \alpha_{bc} + m_4 . \beta_2 + H_d . \delta_1 + H_f . \gamma_2 = \theta_{ba} \\
&\text{ABE} \ldots m_1 . \beta_1 + m_2 . \alpha_{ba} + (m_2 + m_3) . \alpha_{be} + H_d . \delta_1 = \theta_{ba} + \frac{\Delta b}{h} \\
&\text{BCF} \ldots m_4 . \alpha_{cb} + m_4 . \alpha_{cf} - m_3 . \beta_2 - m_3 . \frac{\Delta_2^{mb}}{h} + m_4 . \frac{\Delta_2^{mc}}{h} + H_f . \delta_2 + H_f . \frac{\Delta_2^{h}}{h} = \frac{\Delta b}{h} \\
&\text{S. c} \ldots m_1 = m_2 + m_3 + m_4
\end{aligned}\right\} \quad (65)$$

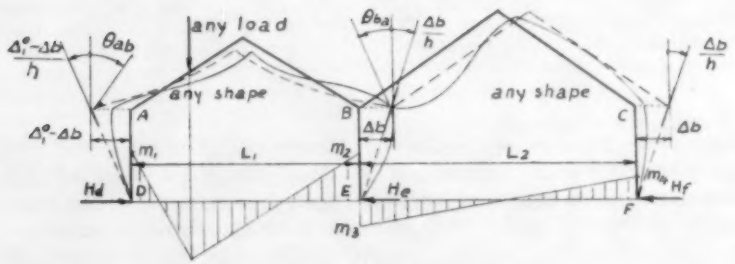

Fig. 38.

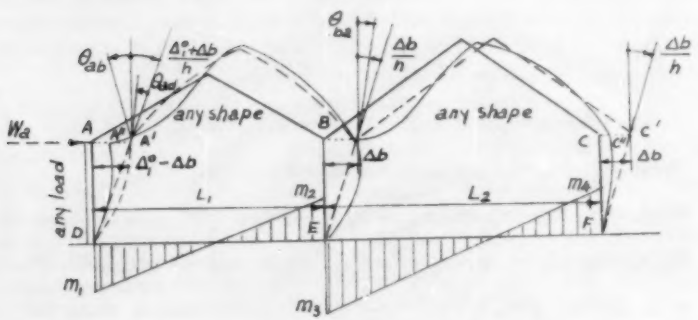

Fig. 39.

Similarly, if a frame is submitted to the action of lateral forces on column AD (*Fig.* 39), equations (64) become

$$\left.\begin{aligned}
&\text{DAB}\ldots m_1\alpha_{ab}+m_1\alpha_{ad}-m_2\cdot\beta_1+m_1\frac{\Delta^{ma}}{h}-m_2\cdot\frac{\Delta^{mb}}{h}+H_d\,\gamma_1+H_d\cdot\frac{\Delta^h}{h}=\theta_{ab}-\theta_{ad}+\frac{\Delta^o+\Delta b}{h}\\
&\text{ABE}\ldots m_2\alpha_{ba}+(m_2+m_3)\alpha_{be}-m_1\beta_1-H_d\cdot\delta_1=\frac{\Delta b}{h}-\theta_{ba}\\
&\text{EBC}.\quad m_3\alpha_{bc}+(m_2+m_3)\alpha_{be}-m_4\beta_2-H_f\cdot\gamma_2=\frac{\Delta b}{h}\\
&\text{BCF}\ldots m_4\alpha_{cb}+m_4\alpha_{cf}-m_3\beta_2-m_3\cdot\frac{\Delta^{mb}_2}{h}+m_4\frac{\Delta^{mc}_2}{h}+H_f\cdot\delta_2+H_f\cdot\frac{\Delta^h_2}{h}=\frac{\Delta b}{h}\\
&\text{S.c}\ldots m_1+m_2+m_3+m_4=W_a\cdot h
\end{aligned}\right\}\quad(66)$$

EXAMPLE.—Statically-indeterminate bending moments for the frame in *Fig.* 40 may be calculated either from (64) if both spans are considered to be loaded at the same time, or from (65) if each span is loaded separately. The elastic constants and load functions are calculated as follows:

Span 1: $EI\alpha = 15{\cdot}55$; $EI\beta = 7{\cdot}775$; $EI\Delta^m = EI\gamma = 139{\cdot}92$; $EI\Delta^h = 2240$

$EI\theta_{ab} = 1020$; $EI\theta_{ba} = 728$; $EI\Delta^o = 12{,}850$.

Span 2: $EI\alpha = \frac{2}{3} \times 32{\cdot}312 = 21{\cdot}54$; $EI\beta = 10{\cdot}77$.

$EI\Delta^m = EI\gamma = \frac{1}{2} \times 16 \times 32{\cdot}312 = 258{\cdot}5$.

$EI\Delta^h = \frac{2}{3} \times 16^2 \times 32{\cdot}312 = 5514{\cdot}53$.

$$EI\varepsilon = \frac{1 \times 20^2 \times 32{\cdot}312}{6 \times 60}(3 \times 60 - 2 \times 20) = 5026{\cdot}3.$$

$$\bar{x} = \frac{2 \times 60^2 - 20^2}{2(3 \times 60 - 2 \times 20)} = 24{\cdot}28 \text{ ft.}; \quad \bar{z} = 35{\cdot}72.$$

$EI\theta_{bc} = 2992{\cdot}3$; $EI\theta_{cb} = 2034$.

$$EI\Delta^o = \frac{1 \times 20^2 \times 16 \times 32{\cdot}312}{12 \times 60^2}(3 \times 60^2 - 2 \times 20^2) = 47{,}869{\cdot}6.$$

For a concentrated load $W = 10{,}000$ lb. on the first span, from (65),

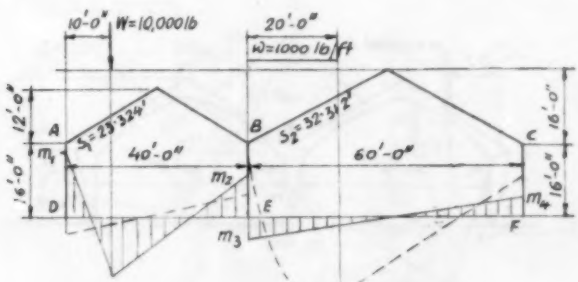

Fig. 40.

$$\text{DAB}\ldots 15{\cdot}55\,m_1 + \tfrac{16}{3}m_1 + 7{\cdot}775\,m_2 + \frac{139{\cdot}92}{16}m_2 + \frac{139{\cdot}92}{16}m_1 + \frac{139{\cdot}92}{16}m_1 + \frac{2240}{16^2}m_1 = 1020 + \frac{12{,}850}{16} - \frac{\Delta b}{h}EI$$

$$\text{ABC}\ldots\ 7{\cdot}775\,m_1 + 15{\cdot}55\,m_2 - 21{\cdot}54\,m_3 + 10{\cdot}77\,m_4 + \frac{139{\cdot}92}{16}m_1 + \frac{258{\cdot}5}{16}m_4 = 728$$

$$\text{ABE}\ldots 7{\cdot}775\,m_1 + 15{\cdot}55\,m_2 + \tfrac{16}{3}(m_2 + m_3) + \frac{139{\cdot}92}{16}m_1 = 728 + \frac{\Delta b}{h}EI$$

$$\text{BCF}\ldots 21{\cdot}54\,m_4 + \tfrac{16}{3}m_4 - 10{\cdot}77\,m_3 - \frac{258{\cdot}5}{16}m_3 + \frac{258{\cdot}5}{16}m_4 + \frac{258{\cdot}5}{16}m_4 + \frac{5514{\cdot}53}{16^2}m_4 = \frac{\Delta b}{h}EI$$

$$\text{S.c}\ldots m_1 = m_2 + m_3 + m_4$$

from which $m_1 = 28{,}943{\cdot}1$ ft.-lb., $m_2 = 18{,}006$ ft.-lb., $m_3 = 6697{\cdot}8$ ft.-lb., and $m_4 = 4239{\cdot}3$ ft.-lb.

For a uniformly-distributed load on part of the second span,

$$\text{DAB}\ldots 21{\cdot}54\,m_1 + \tfrac{16}{3}m_1 + \frac{258{\cdot}5}{16}m_1 + 10{\cdot}77\,m_2 + \frac{258{\cdot}5}{16}m_2 + \frac{258{\cdot}5}{16}m_1 + \frac{5514{\cdot}43}{16^2}m_1 = 2034 + \frac{47{,}869{\cdot}6}{16} - \frac{\Delta b}{h}EI$$

$$\text{ABC}\ldots 10{\cdot}77\,m_1 + 21{\cdot}54\,m_2 + 15{\cdot}55\,m_3 - 7{\cdot}775\,m_4 + \frac{258{\cdot}5}{16}m_1 + \frac{139{\cdot}92}{16}m_4 = 2992{\cdot}3$$

$$\text{ABE}\ldots 10{\cdot}77\,m_1 + 21{\cdot}54\,m_2 + \tfrac{16}{3}(m_2 - m_3) + \frac{258{\cdot}5}{16}m_1 = 2992{\cdot}3 + \frac{\Delta b}{h}EI$$

$$\text{BCF}\ldots 15{\cdot}55\,m_4 + \tfrac{16}{3}m_4 - 7{\cdot}775\,m_3 - \frac{139{\cdot}92}{16}m_3 + \frac{139{\cdot}92}{16}m_4 + \frac{139{\cdot}92}{16}m_4 + \frac{2240}{16^2}m_4 = \frac{\Delta b}{h}EI$$

$$\text{S.c}\ldots m_1 = m_2 - m_3 + m_4$$

from which $m_1 = 4801{\cdot}5$ ft.-lb., $m_2 = 26{,}913{\cdot}6$ ft.-lb., $m_3 = 65{,}295{\cdot}3$ ft.-lb., and $m_4 = 43{,}183{\cdot}2$ ft.-lb.

EXAMPLE.—The load functions and elastic constants for a single-span frame are :

Beam : $EI\alpha = 35{\cdot}8$; $EI\beta = 26{\cdot}86$; $EI\Delta^m = EI\gamma = 611$; $EI\Delta^h = 12{,}800$.

$EI\theta_{ab} = 4041{\cdot}2$; $EI\theta_{ba} = 3423{\cdot}6$; $EI\Delta^o = 76{,}546$.

Column : $EI\alpha_c = 2{\cdot}07$.

For the two-span frame shown in *Fig.* 41, from equations (65) :

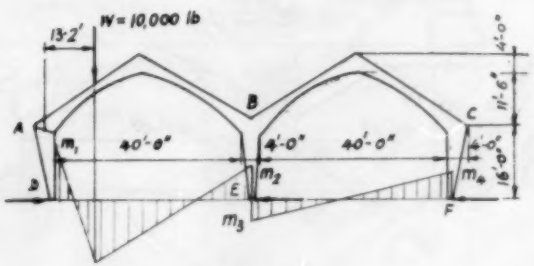

Fig. 41.

$$DAB\ldots 35{\cdot}80m_1+2{\cdot}07m_1+26{\cdot}86m_2+\frac{611}{16}m_1+\frac{611}{16}m_2+\frac{611}{16}m_1+\frac{12,800}{16^2}m_1=4041{\cdot}2+\frac{76,546}{16}-\frac{\Delta b}{h}EI$$

$$ABC\ldots 26{\cdot}86m_1+35{\cdot}80m_2-35{\cdot}80m_3+26{\cdot}86m_2+\frac{611}{16}m_1+\frac{611}{16}m_4=3423{\cdot}6$$

$$ABE\ldots 26{\cdot}86m_1+35{\cdot}80m_2+2{\cdot}07(m_2+m_3)+\frac{611}{16}m_1=3423{\cdot}6+\frac{\Delta b}{h}EI$$

$$BCF\ldots 35{\cdot}80m_4+2{\cdot}07m_4-26{\cdot}86m_3-\frac{611}{16}m_3+\frac{611}{16}m_4+\frac{611}{16}m_4+\frac{12,800}{16^2}m_4=\frac{\Delta b}{h}EI$$

$$S.c.\ldots m_1=m_2+m_3+m_4$$

from which $m_1 = 46{,}608{\cdot}4$ ft.-lb., $m_2 = 14{,}729{\cdot}9$ ft.-lb., $m_3 = 21{,}910$ ft.-lb., and $m_4 = 9968{\cdot}5$ ft.-lb.

Continuous Frames of Three and Four Spans with Curved Members.

When analysing three-span frames with curved members (*Fig.* 42), at least one linear gap will have to be considered in addition to the usual angular gaps at each joint. If it is assumed that joint B is at its final position at B′, and column CG is at its final position at C″G, points A′, C′, and D′, for frames in

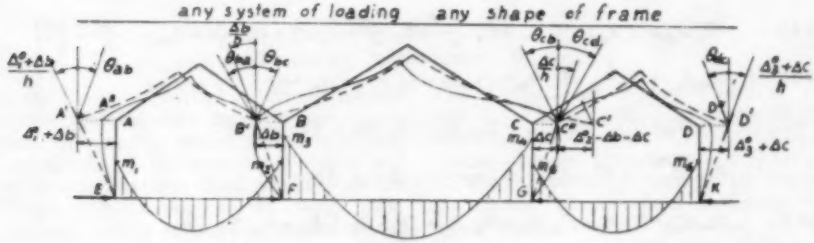

Fig. 42.

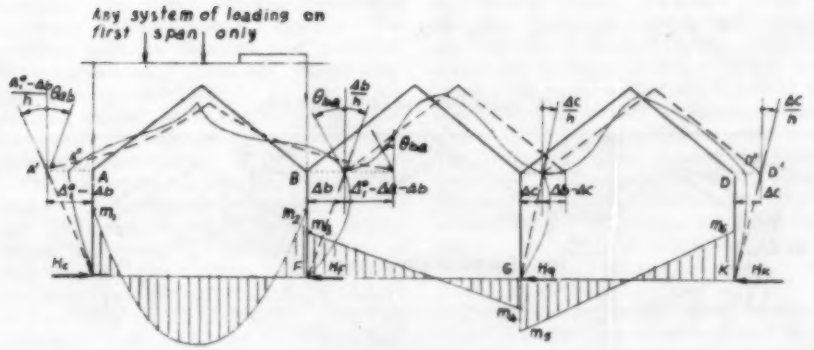

Fig. 43.

a statically-determinate condition, will move finally to A″, C″, and D″ when statically-indeterminate bending moments and forces are applied. At joint C there will be a linear gap of $(\Delta_2^o - \Delta b - \Delta c)$, which must be closed simultaneously with all angular gaps. For any shape of frame, and any system of loading, the equations of equilibrium can be set out as in (67).

$$
\left.\begin{aligned}
&\text{EAB} \ldots m_1\alpha_{ab} + m_1\alpha_{ae} + m_2\beta_1 + m_2\frac{\Delta_1^{mb}}{h} + m_1\frac{\Delta_1^{ma}}{h} + H_e\gamma_1 + H_e\frac{\Delta_1^h}{h} = \theta_{ab} + \frac{\Delta_1^o}{h} + \frac{\Delta b}{h}\\
&\text{ABC} \ldots m_1\beta_1 + m_2\alpha_{ba} + m_3\alpha_{bc} + m_4\beta_2 + H_e\delta_1 + (H_e + H_f)\gamma_2 = \theta_{ba} + \theta_{bc}\\
&\text{FBC} \ldots m_3\alpha_{bc} + (m_3 - m_2)\alpha_{bf} + m_4\beta_2 + (H_e + H_f)\gamma_2 = \theta_{bc} + \frac{\Delta b}{h}\\
&\text{C} \quad \ldots m_3\Delta_2^{mb} + m_4\Delta_2^{mc} + (H_e + H_f)\Delta_2^h = \Delta_2^o - \Delta b - \Delta c\\
&\text{BCD} \ldots m_3\beta_2 + m_4\alpha_{cb} + m_5\alpha_{cd} + m_6\beta_3 + (H_e + H_f)\delta_2 + H_\kappa\gamma_3 = \theta_{cb} + \theta_{cd}\\
&\text{BCG} \ldots m_3\beta_2 + m_4\alpha_{cb} + (m_4 - m_5)\alpha_{cg} + (H_e + H_f)\delta_2 = \theta_{cb} + \frac{\Delta c}{h}\\
&\text{CDK} \ldots m_6\alpha_{dc} + m_6\alpha_{dk} + m_5\beta_3 + m_5\frac{\Delta_3^{mc}}{h} + m_6\frac{\Delta_3^{md}}{h} + H_\kappa\delta_3 + H_\kappa\frac{\Delta_3^h}{h} = \theta_{dc} + \frac{\Delta_3^o}{h} + \frac{\Delta c}{h}\\
&\text{Sc} \ldots m_1 + m_3 - m_2 = m_4 - m_5 + m_6
\end{aligned}\right\} \quad (67)
$$

$$
\left.\begin{aligned}
&\text{EAB} \ldots m_1\alpha_{ab} + m_1\alpha_{ae} + m_2\beta_1 + m_2\frac{\Delta_1^{mb}}{h} + m_1\frac{\Delta_1^{ma}}{h} + H_e\gamma_1 + H_e\frac{\Delta_1^h}{h} = \theta_{ab} + \frac{\Delta_1^o}{h} - \frac{\Delta b}{h}\\
&\text{ABC} \ldots m_1\beta_1 + m_2\alpha_{ba} - m_3\alpha_{bc} + m_4\beta_2 + H_e\delta_1 + (H_e - H_f)\gamma_2 = \theta_{ba}\\
&\text{FBC} \ldots m_3\alpha_{bc} + (m_3 + m_2)\alpha_{bf} - m_4\beta_2 - (H_e - H_f)\gamma_2 = \frac{\Delta b}{h}\\
&\text{C} \quad \ldots m_4\Delta_2^{mc} - m_3\Delta_2^{mb} + (H_e - H_f)\Delta_2^h = \Delta b - \Delta c\\
&\text{BCD} \ldots m_4\alpha_{cb} - m_3\beta_2 - m_3\alpha_{cd} + m_6\beta_3 + (H_e - H_f)\delta_2 + H_\kappa\gamma_3 = 0\\
&\text{BCG} \ldots m_4\alpha_{cb} - m_3\beta_2 + (m_4 + m_5)\alpha_{cg} + (H_e - H_f)\delta_2 = \frac{\Delta c}{h}\\
&\text{CDK} \ldots m_6\alpha_{dc} + m_6\alpha_{dk} - m_5\beta_3 - m_5\frac{\Delta_3^{mc}}{h} + m_6\frac{\Delta_3^{md}}{h} + H_\kappa\delta_3 + H_\kappa\frac{\Delta_3^h}{h} = \frac{\Delta c}{h}\\
&\text{Sc} \ldots m_1 = m_2 + m_3 + m_4 + m_5 + m_6
\end{aligned}\right\} \quad (68)
$$

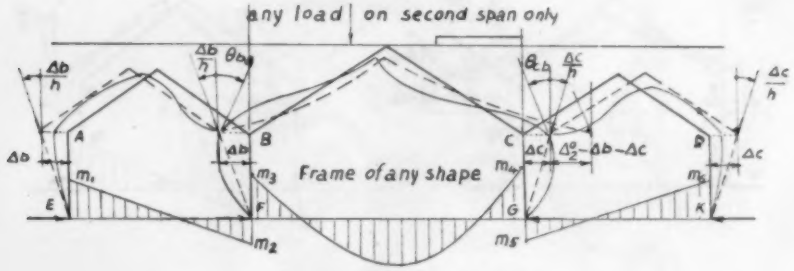

Fig. 44.

For symmetrical frames with symmetrical loading the first four equations only are required. If the first span only is loaded (*Fig.* 43), equations (67) require slight alteration as in (68).

If the second span only is loaded (*Fig.* 44), equations (67) become

$$
\left.
\begin{aligned}
&EAB\ldots m_1.\alpha_{ab}+m_1.\alpha_{ae}-m_2.\beta_1-m_2.\frac{\Delta_1^{mb}}{h}+m_1.\frac{\Delta_1^{me}}{h}+H_e.\gamma_1+H_e.\frac{\Delta_1^{h}}{h}=\frac{\Delta b}{h}\\
&ABC\ldots m_1.\beta_1-m_2\alpha_{ba}+m_3\alpha_{bc}+m_4.\beta_2+H_e\delta_1+(H_e+H_f).\gamma_2=\theta_{bc}\\
&FBC\ldots m_3.\alpha_{bc}+(m_2+m_3).\alpha_{bf}+m_4.\beta_2+(H_e+H_f).\gamma_2=\theta_{bc}+\frac{\Delta b}{h}\\
&C\quad\ldots m_3.\Delta_2^{m}+m_4.\Delta_2^{m}+(H_e+H_f).\Delta_2^{h}=\Delta_2^{o}-\Delta b-\Delta c\\
&BCD\ldots m_3.\beta_2+m_4.\alpha_{cb}-m_5.\alpha_{cd}+m_6.\beta_3+(H_e+H_f)\delta_2+H_K.\gamma_3=\theta_{cb}\\
&BCG\ldots m_3.\beta_2+m_4.\alpha_{cb}+(m_4+m_5)\alpha_{cg}+(H_e+H_f).\delta_2=\theta_{cb}+\frac{\Delta c}{h}\\
&CDK\ldots m_6.\alpha_{dc}+m_6.\alpha_{dk}-m_5.\beta_3-m_5.\frac{\Delta_3^{mc}}{h}+m_6.\frac{\Delta_3^{md}}{h}+H_K.\delta_3+H_K.\frac{\Delta_3^{h}}{h}=\frac{\Delta c}{h}\\
&S.c.\ldots m_1+m_2+m_3=m_4+m_5+m_6.
\end{aligned}
\right\}\quad(69)
$$

(To be continued.)

Training in Concrete Work.

So far thirty-six technical schools intend to offer the course for foremen and supervisors of concrete work referred to in our July number. The courses will consist of two-hourly sessions held weekly for 24 weeks from September to May. The City and Guilds of London Institute will hold examinations in May, 1955, and successful candidates will be awarded a Certificate in Concrete Practice. Prizes are also being offered by the Reinforced Concrete Association and the Prestressed Concrete Development Group. The syllabus includes lectures and practical work on concrete materials, proportioning, mixing, machinery, placing, compaction, curing, testing, shuttering, reinforcement, prestressed concrete, and precast products.

The following schools are offering the course: Birmingham College of Technology, Bridgend Technical College, Bristol School of Technology, Brixton School of Building, Bromley College of Art, Burton-on-Trent Technical College, Cardiff College of Technology and Commerce, Coventry Technical College, Crewe Technical College, Croydon Polytechnic, South East Essex Technical College and School of Art (Dagenham), Derby Technical College, East Ham Technical College, Heriot-Watt College (Edinburgh), Falkirk County Trades School, Hammersmith School of Building, Hereford College of Further Education, Huddersfield Technical College, King's Lynn Technical College, Lancaster and Morecambe College of Further Education, Liverpool College of Building, Maidstone Technical College, Rutherford College of Technology (Newcastle-upon-Tyne), Newport (Isle of Wight) Technical College, Nottingham and District Technical College, Plymouth Technical College, North Lindsey Technical College (Scunthorpe), Sheffield College of Commerce and Technology, Southend-on-Sea Municipal College, Southampton Technical College, Stroud and District Technical College, South East London Technical College (Sydenham), Twickenham Technical College, Willesden Technical College, Wolverhampton and Staffordshire Technical College, York Technical College.

Employers and employees interested in these courses should write direct to the schools for the syllabus and further information.

A Roof Cantilevering 111 ft.

THE roof of the grandstand (*Fig.* 1) of the stadium at Casablanca, French Morocco, is built in five parts, each completely independent of the adjacent parts, in order to eliminate the effects of shrinkage of the concrete and movements due to changes of temperature. The length of the outer side of the roof is 432 ft. and that of the inner side is 342 ft.; the width is 140 ft., of which 111 ft. is cantilevered beyond the row of internal columns.

Each part of the roof is supported by four columns; two are at the rear, and 28 ft. in front of these are two internal columns which pass through the stands. The main members of each part of the roof comprise two concrete trusses, each extending from the rear columns and passing over the internal columns beyond which they cantilever. The trusses are triangular as shown in *Fig.* 1. The lower boom of each truss is straight, varying in cross section from 2 ft. by 1 ft. 4 in. to 3 ft. by 2 ft. 6 in., and reinforced by ten 16-mm. bars and twenty-four 32-mm. bars. This member is always in compression. The upper boom is 2 ft. by 1 ft. 4 in. at its ends and increases to 3 ft. by 3 ft. 4 in. over the internal columns. The reinforcement varies from six to thirty-six 40-mm. bars. A medium high-tensile steel was used which was unsuitable for welding and the bars were lapped where necessary for a length of 75 diameters, the number of stirrups being increased over the lengths of the laps. Vertical and inclined web members are used to form an N-truss. The arrangement of the truss reduces the secondary bending moments at the joints. The trusses support transverse beams carrying secondary beams on which is a thin slab.

The internal columns, always in compression, are T-shaped in cross section and are 3 ft. by 4 ft. 2 in. overall. They are supported on bases 14 ft. square by 6 ft. 6 in. deep. These columns also support the stands. Under the worst conditions of loading, including that due to wind, the ground pressure does not exceed 5½ tons per square foot. The columns at the rear are rectangular, 3 ft. by 2 ft. 8 in., and are reinforced by eighteen 40-mm. bars that extend into the trusses and the counterweights provided at the bases of the columns. The counterweights are octagonal on plan, 23 ft. 3 in. across the flats and about 10 ft. thick.

Fig. 1.

The shutters for the roof were supported on tubular scaffolds mounted on trolleys so that after the shutters had been struck they could be pushed directly to the next part to be concreted. Striking of the shutters was carried out slowly to reduce the deflection of the cantilevers; for the first part of the roof striking took eight hours and for the remaining four parts five hours each. The average deflection at the ends of the cantilevers was about 5½ in.

The architect is M. Dangleterre and the consulting engineer is M. Henry Lossier. The foregoing is abstracted from the French journal "La Technique Moderne —Construction" for July, 1954.

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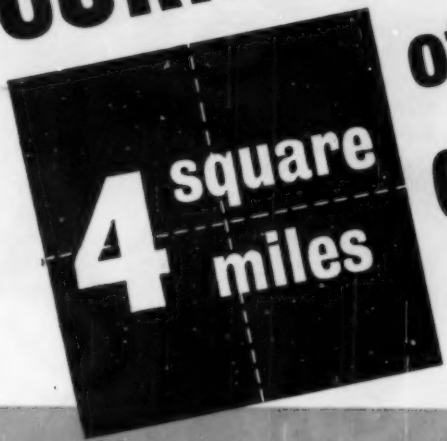

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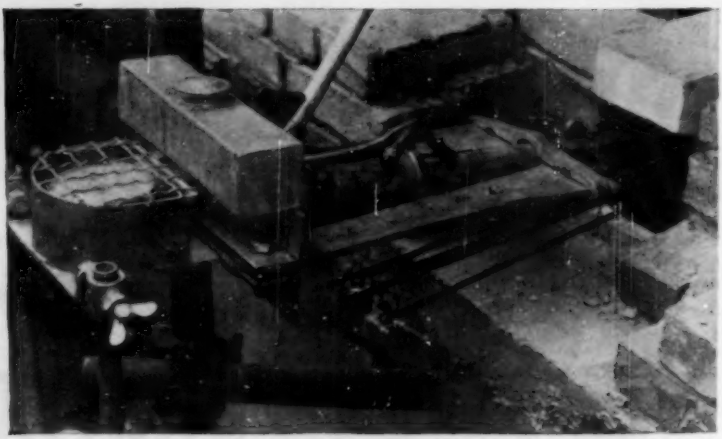

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An Articulated Groyne.

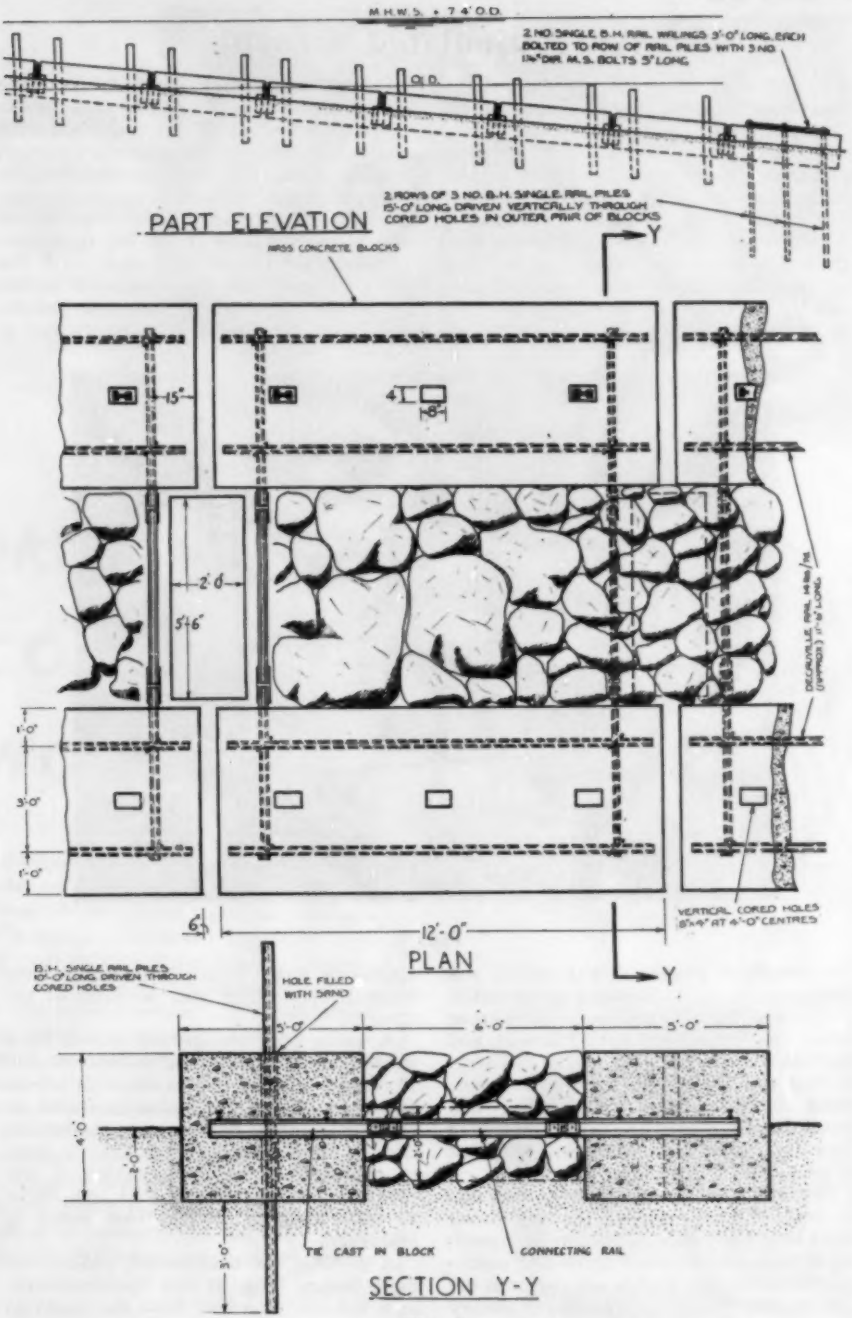
THE groyne at Selsey Bill, shown in *Fig.* 1, was designed to meet very exceptional circumstances. The rate of erosion east of the groyne has averaged 20 ft. to 30 ft. per annum, whereas to the west erosion has averaged only 3 ft. to 4 ft. per annum. The point of Selsey Bill was protected by strong concrete and timber defences until the outbreak of the 1939–1945 war, but by 1953 these defences had disintegrated and the debris lay scattered over the foreshore between high and low water, except for one short length of wall which was being rapidly outflanked and undermined. If this wall had been allowed to collapse Selsey Bill would soon have followed, and the task of protecting the residential areas of East and West Selsey would have been much more difficult and costly, and would have included the abandonment of developed areas because of the great cost of protecting them.

Fig. 1.

The first work undertaken in 1953 was to seal off and stabilise the remaining short length of concrete wall by surrounding it with a sheet-piled apron and carrying the sheet-piled bulkheads well into the cliff on either side. It was also necessary to stabilise the beach. The debris of the old defences made an effective rubble groyne, but wave action combined with the tide which sweeps westward around the Bill during the ebb tide were disturbing factors and the lack of continuity was a source of weakness. The exposure of the site to storms from all directions between south-west and east, and the danger arising from the presence of masses of heavy wave-driven concrete rubble, precluded the use of a piled groyne of timber or steel, even if piles could have been driven, which was doubtful at the time.

A plain concrete groyne would have necessitated a sheet-piled foundation and would have been very costly. It would also have been a rigid structure and, as such, incapable, except at considerable cost, of being adapted from time to time to changes in the configuration of the coastline and foreshore that are likely to take place before the east beach is stabilised.

A flexible, or articulated, plain concrete groyne (*Fig.* 2) was therefore built in a S.S.-E. direction from the point of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PLAN
Y
B.H. SINGLE RAIL PILES 10'-0" LONG, DRIVEN THROUGH CORED HOLES
HOLE FILLED WITH SAND
5'-0"
6'-0"
5'-0"
4'-0"
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Fig. 2.

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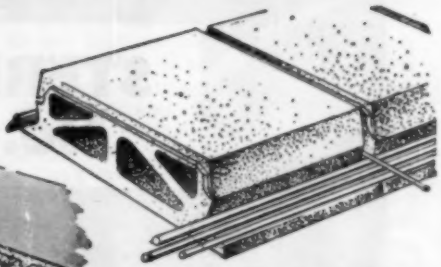

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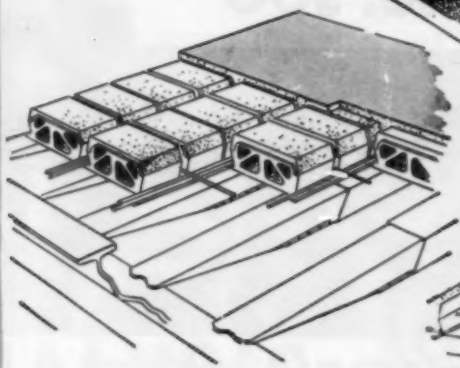

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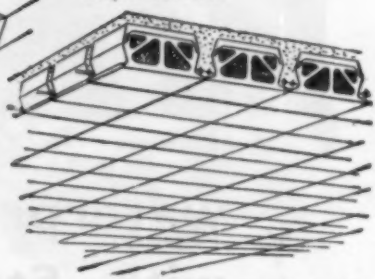

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the Bill. This consists of two parallel rows of concrete blocks, cast in situ and weighing 15 tons each, which are free to settle independently of one another but are held together below beach level by a flexible linkwork made up from lengths of bull-head rail. The rails project from the ends of each block, where they are bolted to a short piece of connecting rail. The space between the two rows of blocks is filled with rubble, while the western row is pinned to the beach by pairs of steel rails driven through holes formed in the blocks so as to penetrate the underlying shingle to a depth of 3 ft., thus providing some resistance to lateral displacement; these rails are dowels and not piles. The rails project above the tops of the blocks to allow for the future heightening or strengthening of the groyne if this be found necessary. A fairly even beach has been held along both sides of the groyne, which has been free to adapt itself, without fracture of its component parts, to seasonal variations in the configuration of the foreshore. The groyne is 200 ft. long and cost £3000.

The concrete was in the proportions of 1 : 2½ : 5, with aggregate of 1½ in. maximum size and rapid-hardening Portland cement. The average compressive strength of cubes was 2300 lb. per square inch at seven days. The concrete was mixed on the cliff, about 10 ft. above the beach, and passed through a chute into the mould for the blocks nearest the cliff. Thereafter the concrete was transported to the shutters over the blocks already cast. Timber shutters were used. The intermediate transverse blocks, which prevent shingle passing through the joints, were cast on the completed part of the groyne.

The groyne was built for the Chichester Rural District Council. Messrs. Lewis & Duvivier are the consulting engineers, and Messrs. R. Robinson & Co. (Contractors), Ltd., the contractors.

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A Small Prestressed Roof.

A FLAT concrete roof with a central skylight (*Fig.* 1) has recently been constructed in Old Bond Street, London. The original proposal was for a reinforced concrete slab supported by steel joists, but because of the difficulty of hoisting the joists up the face of the building and over a mansard roof, it was decided to use small precast concrete units which could be taken to the top floor in the passenger lift and then prestressed together. All the units were light enough to be lifted by hand. The heaviest was 3 ft. long, 10 in. deep, and 5½ in. wide and weighed 165 lb. The longest was 5 ft. 3½ in. long by 4 in. wide by 7 in. deep and weighed 147 lb.

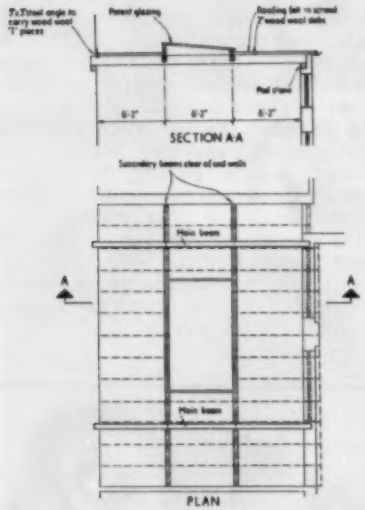

Fig. 1.

The part of the roof to be covered was 18 ft. by 25 ft. The two main beams span in the 18-ft. direction, and were placed at about 4 ft. 6 in. from each end of the roof. The two secondary beams span in the 25-ft. direction. In order not to interfere with the end walls, the secondary beams were cantilevered beyond the two main beams instead of resting on the end walls. Transverse holes were provided in the main beams at the junctions with the secondary beams to allow for the passage of the prestressing cables in the secondary beams.

The units were prestressed in position (*Fig.* 2), using the Gifford-Udall-C.C.L. system. Scaffolding was erected beneath the beam, the units placed upon it, and rubber sleeves placed in recesses formed

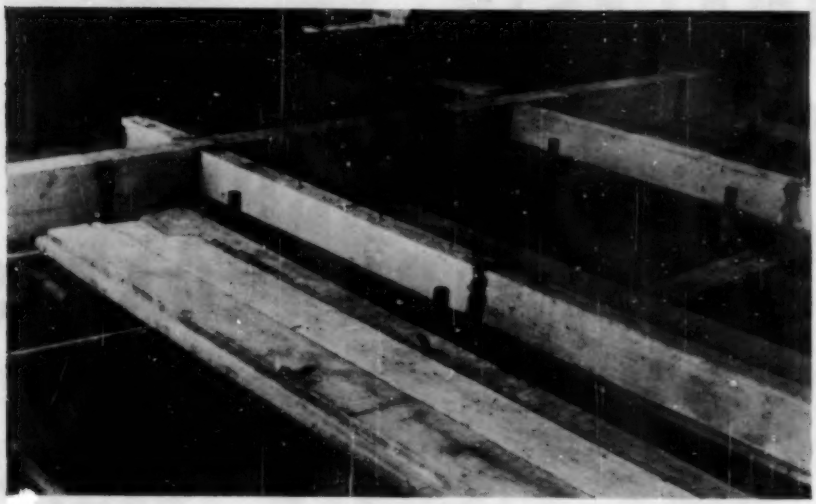

Fig. 2.—The Roof Beams.

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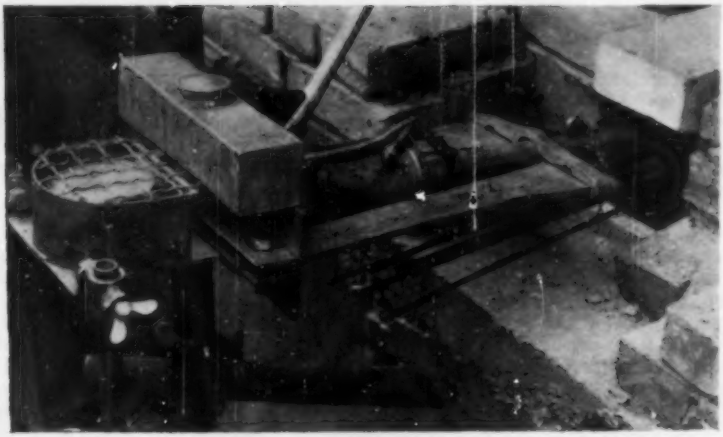


Fig. 3.—Tensioning the Wires.

in the ends of the units to make the cable duct continuous and to prevent the grouting mortar from entering the duct.

After three days the cables were passed through the holes and tensioned (*Fig.* 3). The main and secondary beams were prestressed separately to avoid cracking at the junction of the two beams. The secondary beams were stressed first with four 0·276-in. diameter wires, and then the main beams were stressed with eight 0·276-in. diameter wires.

The roof slab is formed of wood-wool slabs 2 in. thick, which are supported on pressed steel T-sections which span the distance of 6 ft. between the secondary beams and the side walls. The ceiling decoration is applied directly to the underside of the slabs.

The cost of the complete roof was 10*s.* 6*d.* per square foot, a saving of 25 per cent. on the estimated cost of a reinforced concrete slab. The architects were Messrs. Bates & Sinning. and the contractors Udalls Prestressed Concrete Co., Ltd., for whom the consulting engineer was Mr. E. W. H. Gifford, B.Sc., A.M.I.C.E.

Lectures on Concrete.

THE following lectures have been arranged by the Ministry of Works. Admission is free.

Lessons from the Continental Motorways. By Professor W. Fisher Cassie. Technical Institute, Nelson Terrace, Stockton-on-Tees. 13 October. 7 p.m.

Essentials of Good Concreting. By E. E. H. Bate, C.B.E. Technical College, Tonbridge Road, Maidstone. 14 October. 7 p.m. Also at Public Library, Vernon Road, Scarborough. 19 October. 7 p.m. By E. H. MacMillen. College of Art, Newarke, Leicester. 20 October. 7.15 p.m.

Lightweight Concrete. By H. A. Hodson. Y.M.C.A. Hall, Shakespeare St., Nottingham. 15 October. 7.15 p.m.

Concrete Placing and Formwork. By A. B. Harman. Gas Showroom, Sandgate Rd., Folkestone. 27 October. 7 p.m.

Lightweight Precast Roof.

In the construction of the roof of a lecture hall and its supporting columns at Monterey, California, U.S.A., lightweight aggregates were used in order to reduce the cost of the foundations which consist of caissons 50 ft. long and 3 ft. diameter.

The roof was supported by four columns designed to resist horizontal forces due to earthquakes. The columns are in the shape of a cross. Two longitudinal beams 87 ft. 6 in. apart and 104 ft. long span between the columns, with which they form a monolithic frame. Seven precast roof trusses (*Fig.* 1) span between the beams. The ends of the upper chord of each fit under the upper flanges of the beams and are supported on a corbel formed on the web of each beam ; steel plates were left projecting from each member and these were welded together to make a connection. The lower chord of each truss, the ends of which normally carry no load, is connected to the beams by welding together bars cast into each member and left projecting for the purpose. The trusses are 18 ft. 8 in. apart and support precast roof slabs 2 ft. 6 in. wide. From the ends of each slab projecting lips rest on the upper chord of the truss, reinforcement bars from the slabs

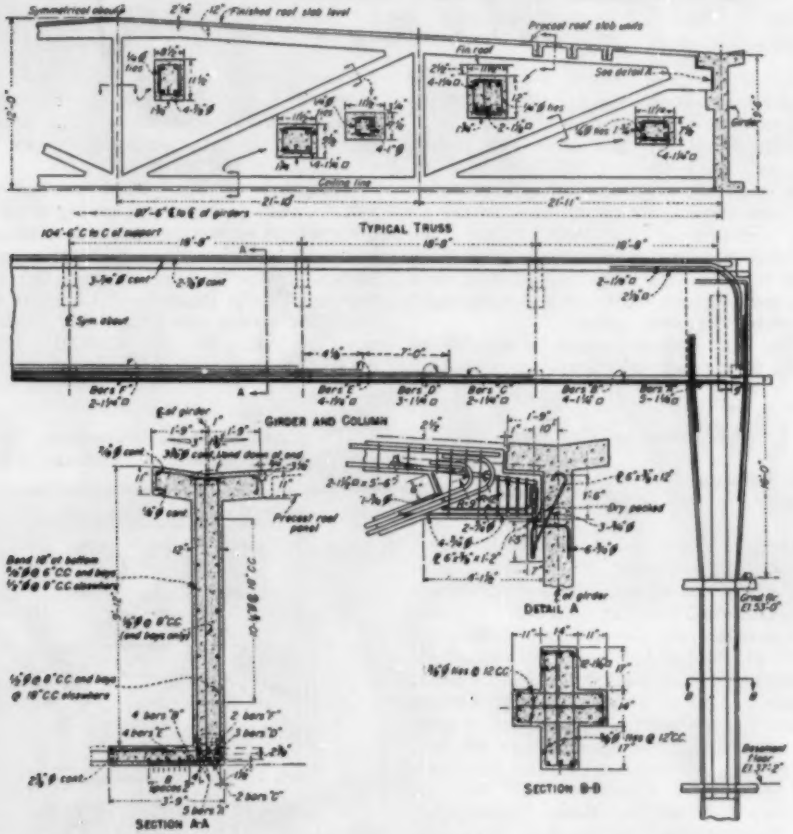
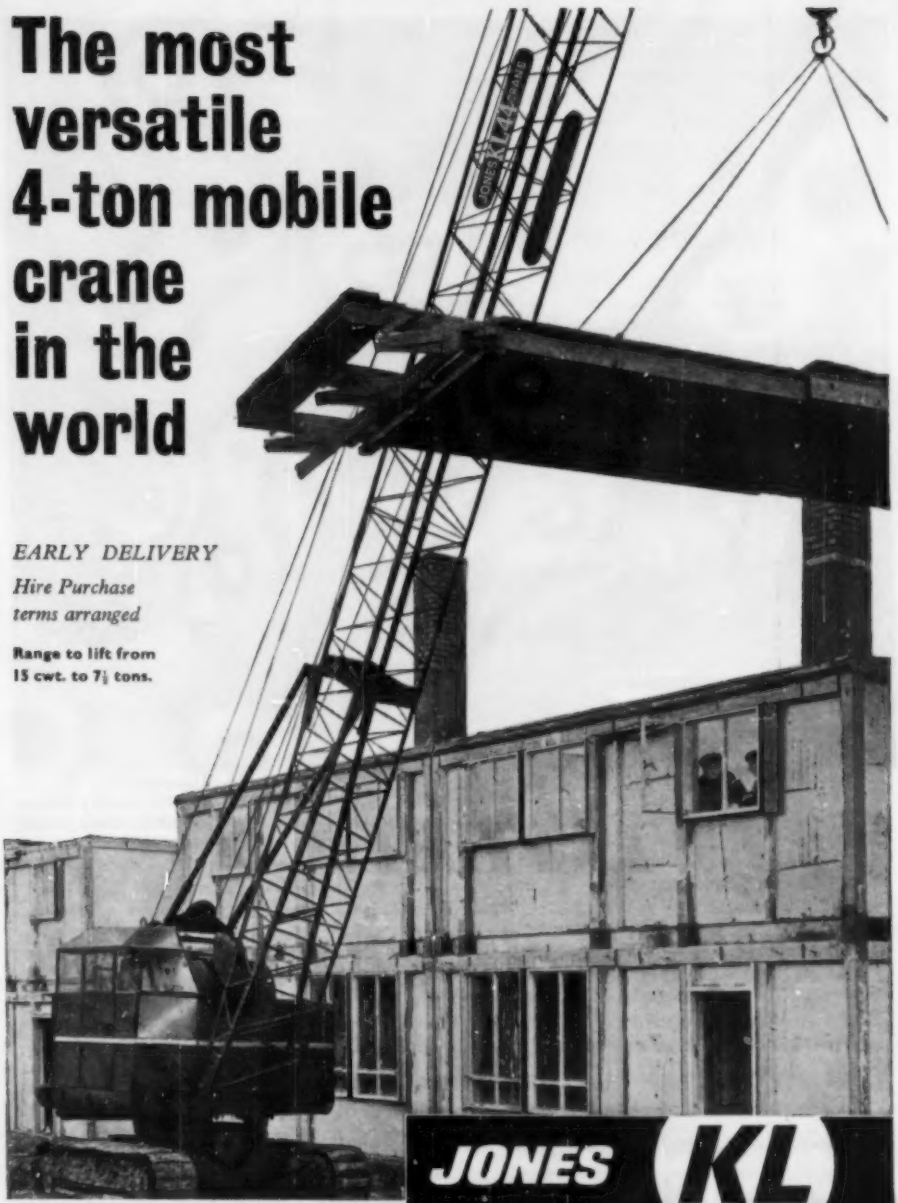


Fig. 1.

The most versatile 4-ton mobile crane in the world



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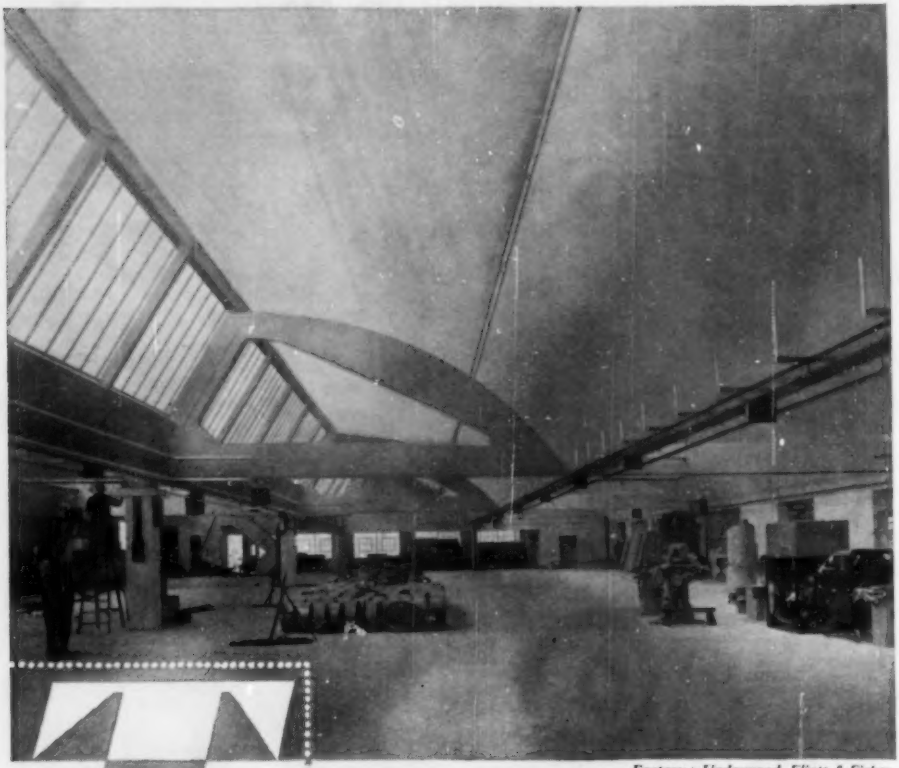


Factory : Underwood, Eliott & Fisher.
Architect : R. Seifert, F.R.I.B.A.
Contractors : Rice & Son Ltd.

TWISTEEL and the Barrel Vault

This is a factory. Light and clean, airy and un-oppressive : it could equally well be a studio, with the curve of the barrel vault roof reflecting the ample north light evenly over broad floor areas. Note the lack of obstruction to the floor space by structural supports : and the absence of dust traps in the clean sweep of the Wireweld-reinforced Twisteel-designed roof.

TWISTEEL REINFORCEMENT LIMITED

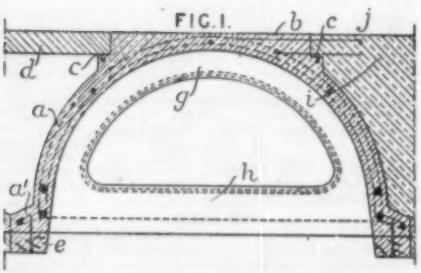
LONDON : 43 UPPER GROSVENOR STREET, W.1. *Tel: GROsvenor 8101 & 1216* . MANCHESTER : 7 OXFORD ROAD MANCHESTER, 1. *Tel: Ardwick 1691* . BIRMINGHAM : ALMA STREET, SMETHWICK, 40. *Tel: Smethwick 1991*
GLASGOW : 19 ST. VINCENT PLACE, GLASGOW, C.1. *Tel: City 6894*

being welded to dowel bars projecting from the truss.

The concrete for the columns, girders, and trusses was made with expanded shale aggregate and has an average crushing strength of 3500 lb. per square inch and a density of 100 lb. per cubic foot. The roof slabs have a density of 80 lb. per cubic foot and were made with pumice aggregate ; the average crushing strength was 2000 lb. per square inch. The structure is described in " Engineering News-Record " for April 22, 1954.

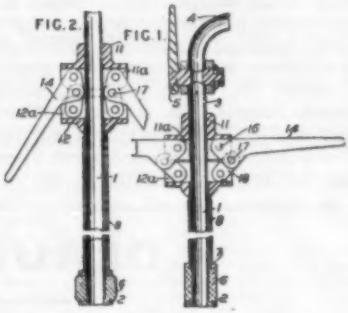
Patents Relating to Concrete.

Floor Beams.



In a floor comprising a self-supporting framework of semi-cylindrical precast beams laid side by side with their cavities facing downwards, each beam has an upper part flattened and shouldered for co-operation with intermediate filler elements, the outer surface of each side of the flattened part forming part of a cylinder, while circumferential stiffening ribs are provided along its inner arcuate surface, the ribs being formed in one with a lower tie-piece which connects the lower edges of the beam together at intervals along its length. In the form shown, the floor consists of a number of arch-like reinforced concrete beams (*a*) laid side by side with their lower edges (a^1) in contact. Each beam has a flat top surface (*b*), each side of which is rebated to form shoulders (*c*). Ribs (*g*), formed integrally with ties (*h*), are formed at intervals along the length of the beam and at the ends thereof. As shown at the left of *Fig.* 1, concrete slabs (*d*) may be positioned with their edges resting on the shoulders (*c*) of adjacent beams, the thickness of the slabs corresponding to the depth of the shoulders, so that a flush floor surface is obtained. Alternatively, and as shown at the right-hand side of *Fig.* 1, plain or reinforced concrete (*i*) may be cast into the spaces between the beams, which may be keyed to the concrete by protruding reinforcements (*j*). The concrete may completely cover the beams. To facilitate the attachment of a ceiling, the beams are provided with nailing strips (*e*) secured to their lower edges (a^1) during casting.—No. 636,486. M. Thinet and G. Heffner. May 1947.

A Device for Grouting.



A device for feeding cement grout into bores for cementation operations consists of a pipe (1) having an abutment (2) at one end, a sealing ring or washer (6), for example, of rubber, surrounding the pipe (1) adjacent to the abutment (2) and a displaceable abutment (7) adapted to compress the ring (6) against the abutment (2) to expand the ring (6) radially and thus to form a seal between the pipe (1) and a bore into which it is inserted. The abutment (7) is at the end of a sleeve (8) which slides over the pipe (1) threaded at (3) for connection to a hose (4) through a cock (5). The sleeve is adapted at its upper end to co-operate with a toggle mechanism to compress the sealing ring between the abutments (2) and (7). The end of the sleeve (8) or a loose washer disposed between the said end and the sealing ring (6) may act in place of the abutment (7). The toggle mechanism embodies a pair of levers (14) with spaced

down-turned flanges each pivoted at points (16) on the upper flange (11*a*) of a bracket (11) screwed to the pipe (1), and also pivoted to one end of a short link (18) at (17) or a pair of parallel links, which is or are pivoted at the other end or ends to the flange (12*a*) of the lower bracket (12), displaceable along the pipe to apply a thrust to the sleeve (8) by downward movement of the levers (14), when the toggles may be automatically locked.

By adjustment of the longitudinal position of the upper bracket (11) threaded to the pipe, the degree of compression applied to the ring (6) can be adjusted and so control the radial expansion of the ring (6). A pair or more of sealing rings, whose inner faces are chamfered or tapered, may be employed. The abutment flanges are then oppositely conical, and a wedge-shaped or conical intermediate ring is arranged between the two sealing rings. In another arrangement two or more sealing rings are disposed one above the other with flat washers between them. No. 639,074. Whitley Moran & Co., Ltd. December 20, 1947.

[Publication of British Patent Specification has been delayed due to the war.]

PROFESSIONAL SERVICES.

PROFESSIONAL SERVICES. Reinforced concrete and steelwork. Design, detail, bar schedules, technical translations. Prompt confidential service. HAM 6350.

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PATENT.

PATENT. It is desired to secure the full commercial development in the United Kingdom of British Patent No. 679,796, which relates to "process for the production of submerged concrete" either by way of the grant of licences or otherwise, on terms acceptable to the patentee. Interested parties desiring copies of the patent specifications should apply to STEVENS, LANGNER, PARRY & ROLLINSON, 5 to 9 Quality Court, Chancery Lane, London, W.C.2.

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FOR SALE. Steel tubes and fittings, all sizes. Cheap prices. List on request. E. STEPHENS & SON, LTD., Bath Street, London, E.C.1.

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(See also facing page.)

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Advertisements must reach this office by the 23rd of the month preceding publication.

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SITUATIONS VACANT. Clarke, Nicholls & Marcel, consulting engineers, require in their London office, for reinforced concrete work, designers and draughtsmen-detailers. Permanent positions. Good prospects. Apply in writing to 21 Westbourne Grove, London, W.2.

SITUATION VACANT. Structural and/or civil engineer (qualified) required for senior position in Scottish firm. Considerable experience of reinforced concrete design essential and some experience of precast and prestressed concrete work preferable. Write, stating qualifications, experience, and salary required. Superannuation and profit-sharing schemes in operation. Box 1980, Robertson & Scott, 42 Charlotte Square, Edinburgh, 2.

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SITUATIONS VACANT. AIR MINISTRY require in London structural engineering designer-draughtsmen in works department for reinforced concrete or structural steelwork, with sound technical training and several years' varied experience in design-detailing of : (*a*) Reinforced concrete construction for all types of buildings, or (*b*) steel-framed sheds, warehouses and similar buildings. Salaries up to £780 p.a., starting pay dependent upon age, qualifications and experience. Extra duty allowance or overtime payable. Promotion prospects. Post non-pensionable with long-term possibilities. Natural born British subjects only. Write, stating age, qualifications, employment details, including type of work done, to Ministry of Labour, 236 Walworth Road, London, S.E.17, quoting Order 82AE.

SITUATION VACANT. Reinforced concrete designer-draughtsman required by Ashmore, Benson, Pease & Co., Stockton-on-Tees. Applicants should be fully experienced in designing and detailing reinforced concrete structures, foundations, and other civil work. Apply stating age, experience, etc., quoting Reference D, to Staff Personnel Officer.

SITUATIONS VACANT. The Trussed Concrete Steel Co., Ltd., have vacancies in their London and Manchester offices for reinforced concrete designers and detailers. Five-days' week. Pension scheme. Apply, giving full particulars of age, education, and previous experience, to the Secretary, Truscon House, 35–41 Lower Marsh, London, S.E.1.

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SITUATION VACANT. Assistant civil engineer required by London firm of consulting engineers. Previous experience essential, with special emphasis on design of water supply and drainage projects. Salary offered will be based on experience and qualifications, which should be summarised in application to Box 4077, Concrete and Constructional Engineering, 14 Dartmouth Street, London, S.W.1.

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(*Continued on page* lx.)

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(*Continued from page* lix.)

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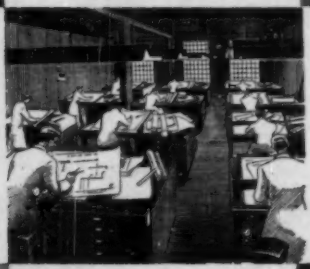

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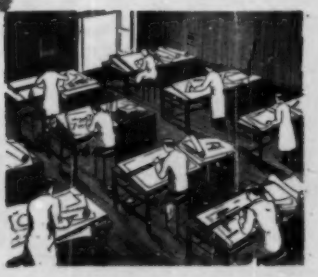

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